Special Report: Bogus Aircraft Parts

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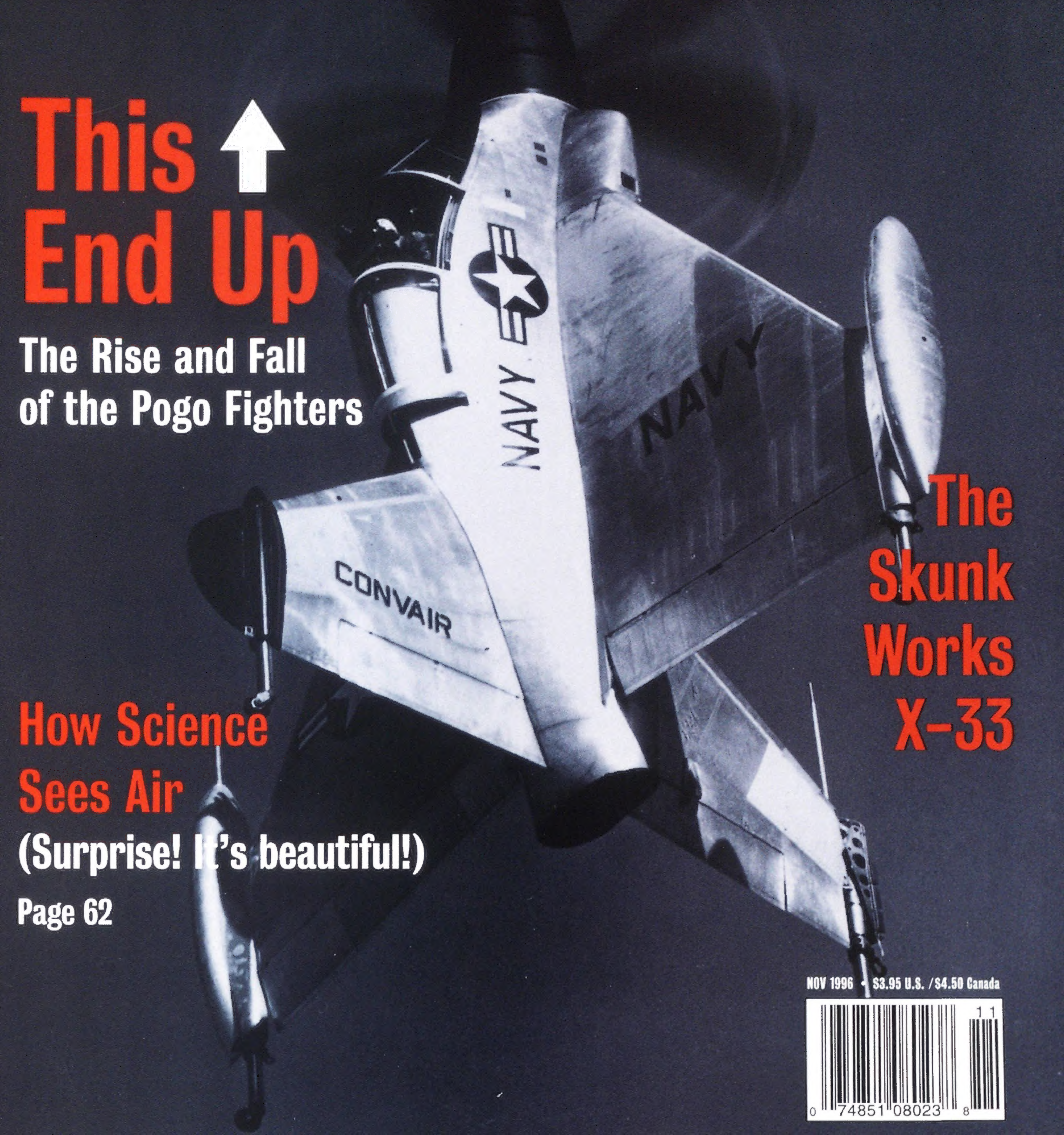

This ↑ End Up

The Rise and Fall of the Pogo Fighters

The Skunk Works X-33

How Science Sees Air

(Surprise! It's beautiful!)

Page 62

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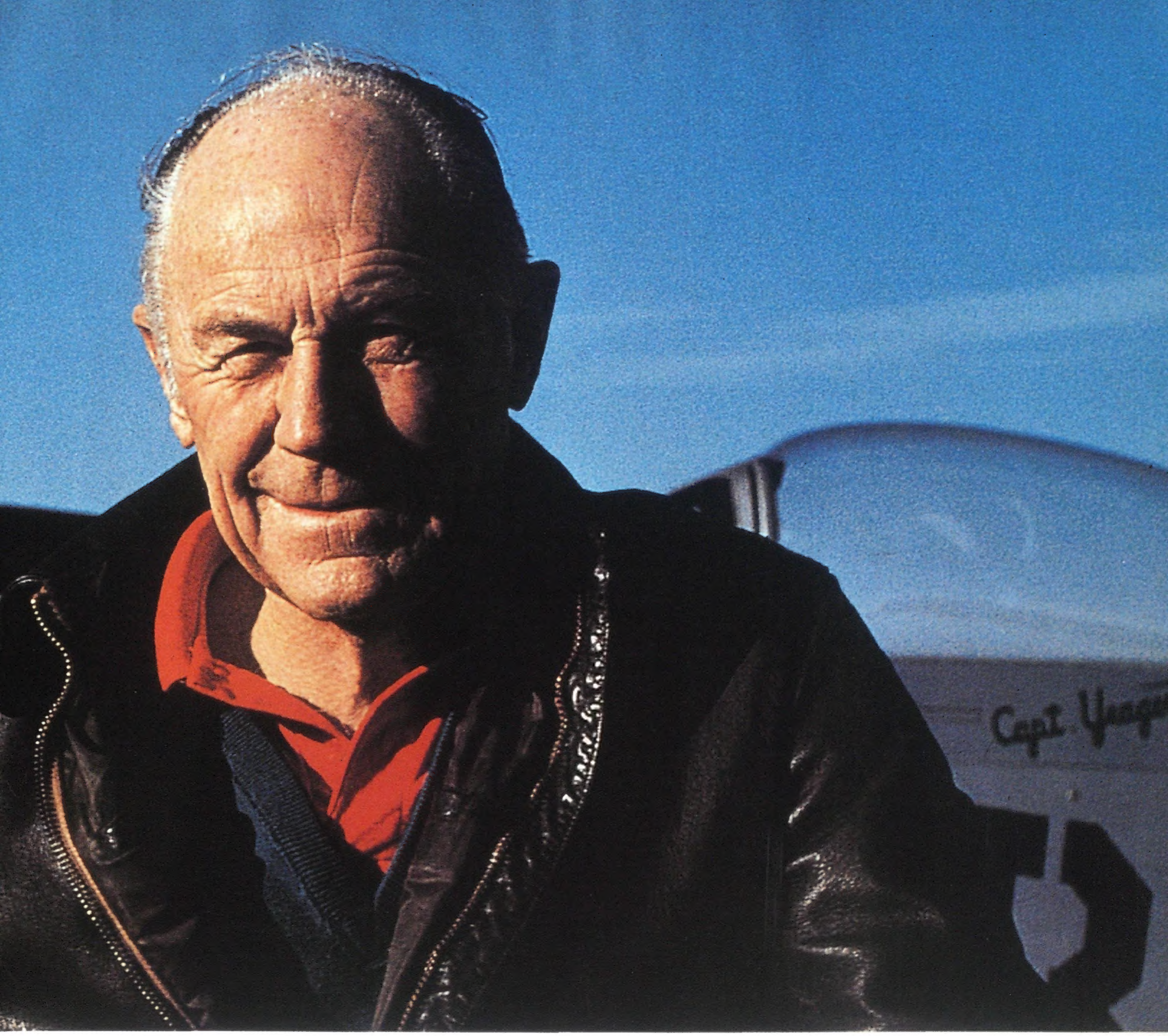
GLAMOROUS



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October/November 1996
Volume 11, Number 4

AIR&SPACE
Smithsonian

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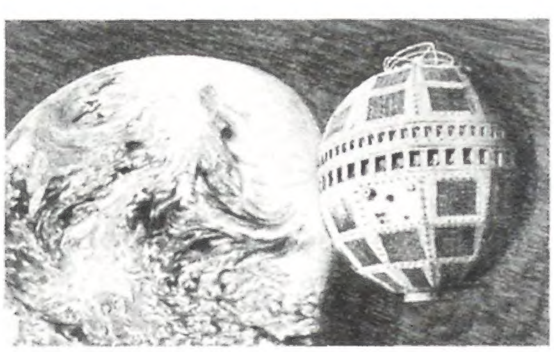

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Cover: In one of only six untethered flights, pilot "Skeets" Coleman guides the Convair XFY-1 through a fall 1954 test. (NASM photo)

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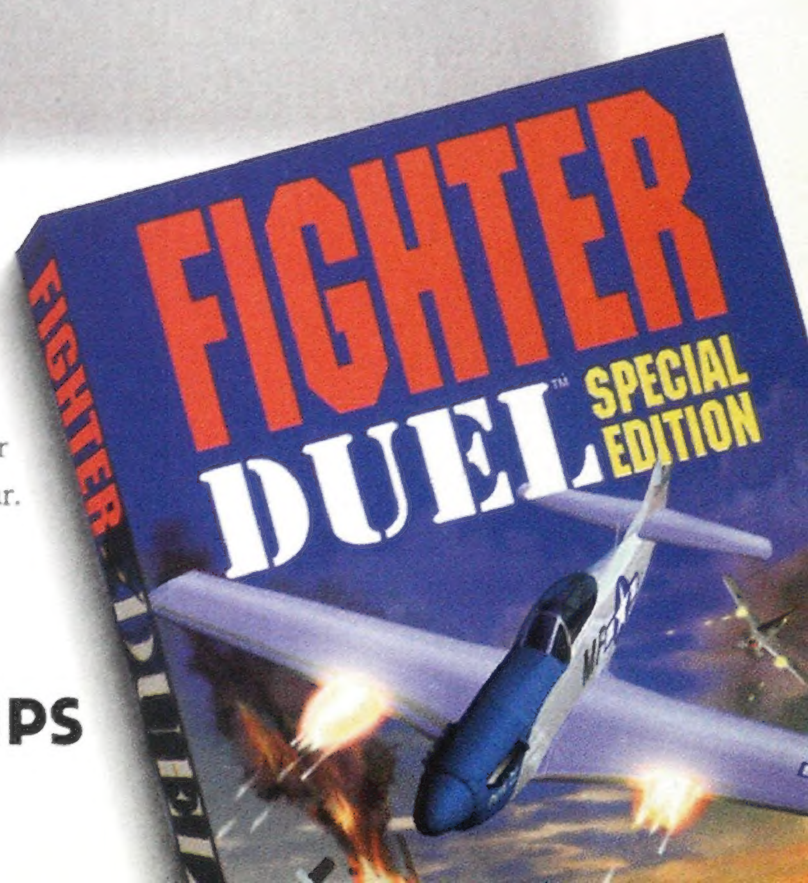
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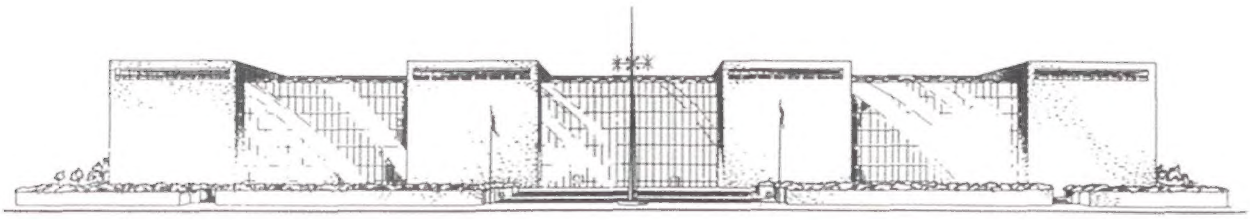

We Go Pogo

Do you ever miss the cold war? You're not alone, and that's part of the inspiration for our occasional series "Reflections on the Cold War" and the installment in this issue, "Going Vertical." When the rivets in the Iron Curtain popped, the world became a much more confusing place. During the long years when the United States and the Soviet Union were locked in an ideological struggle for dominance, the diplomatic decisions were simple: Choose one side or the other and live with the result. But an up side to the rivalry was that both powers were engaged in a competition for technological supremacy, and paranoia can produce wondrous works.

Beginning in the 1950s and accelerating until the late 1980s, the race for world technological leadership produced great benefits. To be sure, the fear of another global war was palpable, and local civil defense drills were nothing to feel good about—the streets of major cities empty of life, schoolkids huddled under their desks. All of it was genuinely scary. But at the same time, the rate of progress in aircraft design and performance during that period seems unmatched by anything before or since.

The notion of building a powerful fighter that could take off vertically from a pad no bigger than a helicopter's is of a piece with the cold war era, if only because without the cold war, you have a hard time imagining its being done at all. There were two such airplanes—one from Convair and the other from Lockheed—and today both seem at the very least a curiosity, and at the very most a bizarre joke. Yet both were deadly serious attempts at defining a whole new way of operating an aircraft and a whole new mission. Helicopters could land and take off vertically, but once airborne, they were too slow to duel with fighters. The "Pogo"-style fighters promised an attractive combination of speed and flexibility (eventually, that promise would be realized in the Harrier). And the reason the airplanes were built at all was because enough people thought they would give us what we wanted in all new airplanes—some tangible advantage over the dreaded Russians.

At least part of the inspiration for a vertical-takeoff scheme was the sudden abundance of power conferred by the advances in turbine engines made during the 1950s and '60s. This was the time of the "century series" fighters—those with designations of F-100 and higher—all of them quite comfortable at Mach 1-plus, courtesy of incredibly powerful afterburning turbojets. Advances in materials in the hot sections of turbines led to higher operating temperatures and more power—for turboprops as well as jets. The Pogos' gigantic turboprop engines had plenty of power, and you had only to harness them to a gearbox that would deliver all that horsepower to the propellers without the whole symphony of metal coming apart.

Today the XFY and XFV seem almost quaint in their embodiment of engineering naïveté. Tail sitters don't work, and now we know that; having become so much wiser we can also wonder why it took building them to figure that out. But at the same time, there is something wonderful about them that says a lot about the climate for designers in that era. The airplanes also speak volumes about the courage of test pilots like "Skeets" Coleman, who actually transitioned from vertical to horizontal and back again in one of them. You'll get to meet Coleman in Stephan Wilkinson's thoughtful account of the life and times of the tail sitters on page 50.

These days, the competition between the superpowers is more like a sibling rivalry, and that takes the edge off our eagerness to dare to attempt what had been unimaginable. Today we seem more eager to tell inventors with wild and whacky ideas to check their brains at the door. In the cautious climate of the future we're unlikely to see anything as marvelously outrageous as those two airplanes ever again, and that's one aspect of the cold war I'll miss.

—George C. Larson

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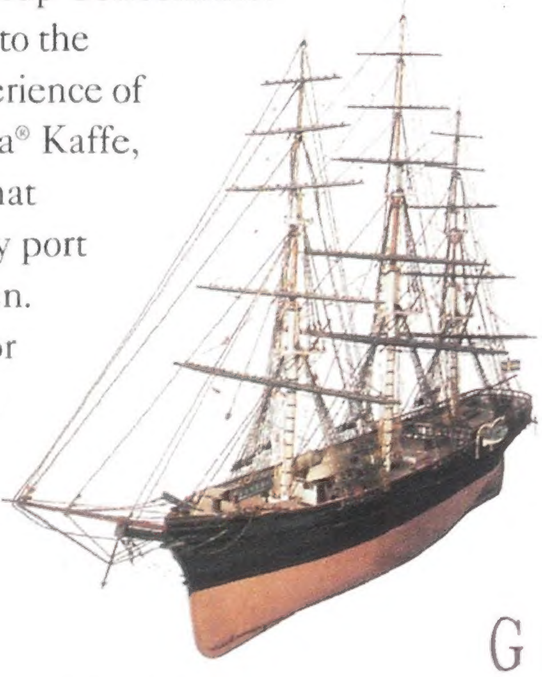

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LETTERS

Nothing to Be Sorry For

I flew every type of fighter that the U.S. Navy and Marines operated in combat in World War II, and as far as maneuverability went, the most impressive of them all was the F2A Buffalo ("The Sorry Saga of the Brewster Buffalo," June/July 1996). It is true that the Buffalo needed an improved fuel tank installation, cockpit pilot armor, increased firepower, stronger landing gear, and wing folding. But that was nothing unusual. Had we patiently improved the design, as the British did their Spitfire series I–XIX, we and our allies in the Pacific theater would have possessed a fighter that was superior to those of the Japanese for the entire duration of the hostilities.

Unfortunately, the Buffalo was plagued by procurement and production policies so inefficient as to be virtually nonexistent, and by financial manipulations that were unsound, if not criminal.

—George C. Carrington
Vancouver, British Columbia

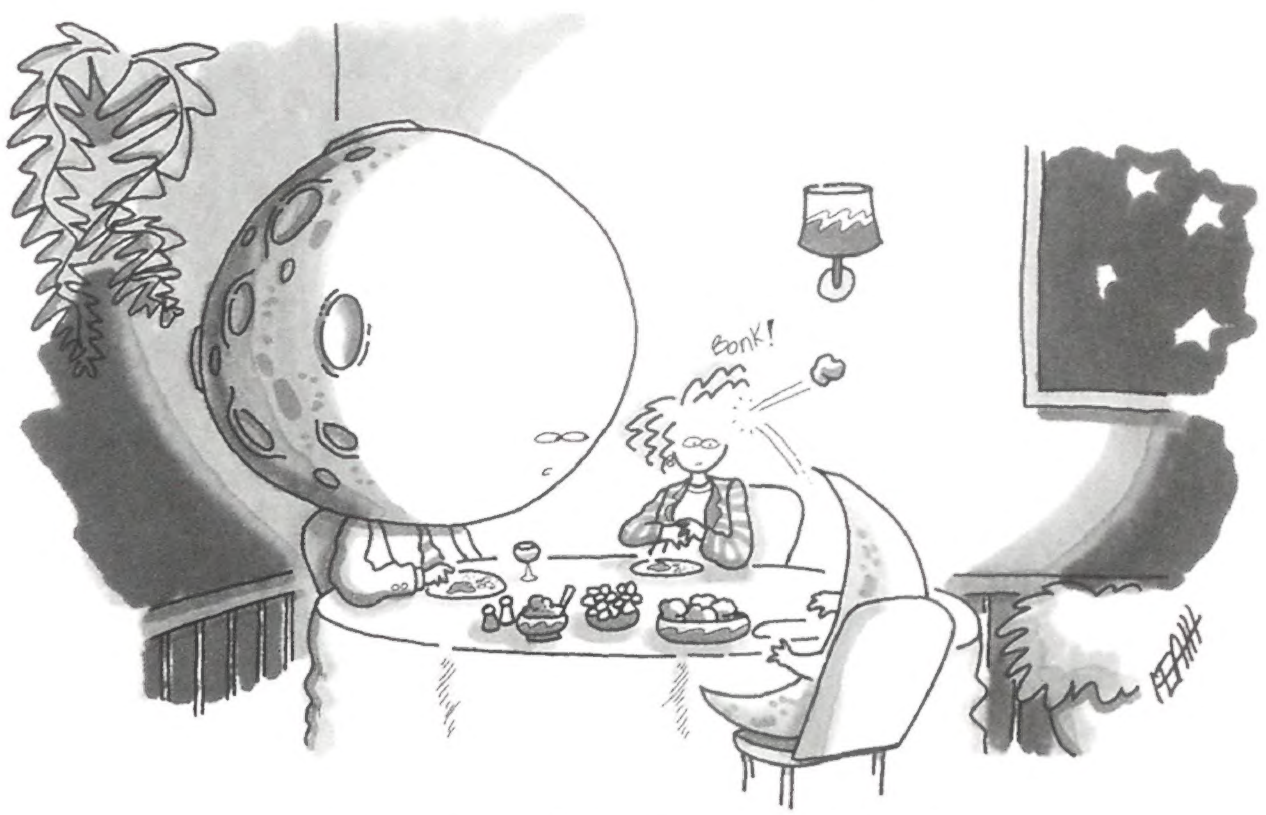
While the Brewster Buffalo does appear in *The World's Worst Aircraft*, take a closer look at that book and you'll see that many World War II aircraft suffered from the Buffalo's problem: lack of a decent engine. The P-51 was a sluggish failure until the Rolls-Royce Merlin was installed, and the P-39 was likewise hobbled by a lower-rated engine and no supercharger.

—Howell Clement
Kalispell, Montana

Come Down to Earth

The air must be pretty thin on top of P.J. Capelotti's ivory tower ("Buried Treasure," Commentary, Aug./Sept. 1996). To compare the recovery of downed aircraft, whether whole or in pieces, to the recovery of artifacts from ancient Troy is ludicrous. If Mr. Capelotti wants to find out how various cultures used these aircraft, he should just dig around in a library. Or better yet, ask his grandpa. He was probably there.

Mr. Capelotti, if you truly are interested in the archeological documentation of



"Excuse my son. He's going through a phase."

aircraft wreck sites, stop alienating and antagonizing aircraft salvagers and instead encourage them to consider the benefits of your professional assistance. Your commentary has done more damage to your profession than I fear you had ever considered.

—Pete Esterle
Uniontown, Ohio

Absence of Malice

In his editorial "Double Whammy" (Viewport, Aug./Sept. 1996), George Larson says that critics of the Federal Aviation Administration envision smoke-filled back rooms in which FAA regulators and airline executives plot ways to undermine safety. You do not have to envision such collusion in order to believe that something is wrong with the current system of airline safety checks and balances. Malicious motives are not the concern. Deregulation produces competition, and competition results in risk, subtly introduced and accepted.

Larson says that businessmen don't want engine fires and smoking holes in the ground, that "if you manufacture airplanes or operate an airline in such a way that you crash a lot, you will soon be out of business." That's of little comfort to the families who have to attend closed-casket ceremonies.

The aviation industry has worked hard and long to engineer and regulate itself to an enviable level of safety, while costs to the consumer have continued to fall. What a shame it is that this progress is undermined by the FAA sitting idly by while substandard parts and procedures are introduced into the system.

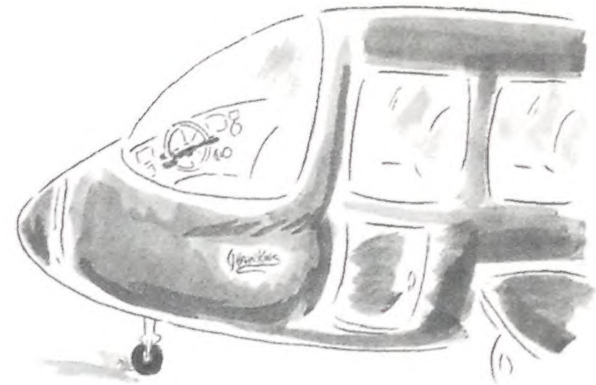
The FAA should not be promoting competition at the same time that it is managing risk. The marketplace determines what kinds of financial pressures are placed on businessmen. Let the businessmen make business decisions. Let the FAA make safety decisions.

I am already making my own decisions, both in the travel agent's office and at the polls.

—Jim Herries
Redlands, California

Anyone Out There Against Safety?

Why should fees for air traffic control service be levied only against users (Viewport, Aug./Sept. 1996)? Everyone who has a vested interest in air safety



should pay, including the non-air traveler who'd prefer not to have an airliner crash into his home.

—Alexis Victor Franco
Alamogordo, New Mexico

Mustang Memories

The Mustang certainly did have more than one contributor ("Who Made the Mustang?" Aug./Sept. 1996). Another one was then-Colonel Mark E. Bradley, who almost single-handedly added the extra internal tankage so important to the aircraft's range capability.

I have recently written some papers (the writer of your article, Peter Garrison, has copies) with two objectives. The first is to explain and quantify the Meredith

Effect of cooling drag reduction. The simple fact is that it was the basis of the Mustang design, and its most efficient application required a buried radiator. My second objective is to give proper credit to the Royal Aircraft Establishment at Farnborough, which sponsored the research that Meredith and R.S. Capon published in 1935 and 1936. Unfortunately, Garrison does not seriously attempt to develop either of these points in his article, though he at least agrees that the principal reason for the Mustang's performance advantage was the cooling system configuration.

In 1939 I saw the same National Advisory Committee on Aviation report on laminar flow that Ed Horkey used for the airfoil, and I noted that the wind tunnel wing models were only some six inches wide and were polished. The writers of the report included a special caveat, which Horkey quite obviously ignored, that no laminar flow extension had been accomplished at anywhere near actual airplane sizes. However, the use of this NACA wing profile did not reduce the Mustang's performance and had some advantages in a high-Mach dive.

Garrison's account of the infighting, backbiting, and resentment of Raymond Rice is exaggerated. Rice was one of the most successful chief engineers of his time, with credit for, among other things, the F-86, F-100, XB-70, and X-15. Perhaps it is not surprising that the North American Aviation engineering department reached new levels of accomplishment under Rice after Horkey and Edgar Schmued took their undisputed talents to other companies.

—J. Leland Atwood
Vista, California

Warning: Humor Ahead

In the last issue's Letters column, Mary Proko was irked by the sexual overtones in "Gossamer Wings" (Flights & Fancy, June/July 1996). I suggest she try reading with her eyes open. The article was an amusing parody of a bad romance novel. I of course had the benefit of enough intelligence to read the introduction, which made that clear.

Ms. Proko said that she "recently had to cancel subscriptions to *Flying* and *Private Pilot* because of articles and a drawing that featured sex." Does Ms. Proko have some rare allergy that will make her head explode if she sees mention of such activity?

—Lylah E. A. Hill
Montclair, California

Well-Adjusted Military Types Need Not Apply

For long-distance missions, the ideal astronaut may not be the toned, well-adjusted military type we usually associate with space travel ("The Loneliness of the Long-Duration Astronaut," June/July 1996). Better adapted might be a dreamy loner who is happiest with his nose stuck in a book. Or one of the millions who have years of experience living with one or two other people in a space no larger than a bathroom, far from home and family, experiencing mostly boredom or fear: penitentiary inmates.

—Robert Howard
Berkeley, California

Aviation—It's a Small World

During World War II and the Korean police action, I served with the Navy and had the opportunity to fly from aircraft carriers and do aerial photography. I also did aerial photography as a civilian, producing work for real estate developers as well as in-flight portraits.

In your 10th anniversary issue, Chad Slattery's aerial photograph of airplanes arranged in an "X" (Sightings, Apr./May 1996) inspired me to attempt a similar photo. I have some airplane models that are in various stages of construction, and I set them out on some black plastic that would simulate a blacktop airfield. Not able to acquire the use of a helicopter, I shot from the balcony above our patio. I enclose the result [below].

—Stephen E. Kanyusik
Sterling Heights, Michigan

Chad Slattery replies: I can relate. At age 12, I would put models of Russian airplanes atop a large glass patio table, crawl underneath, and shoot upwards to make the airplanes seem to be flying across the sky.

Dollars and Sensors

It's time the public knew what the "cheap" Clementine mission really cost. In "The New Millennium" (Aug./Sept. 1996) William Burrows acknowledges that the spacecraft's sensors had been developed through the taxpayer-funded Strategic Defense Initiative and Ballistic Missile Defense Organizations, but what he does not say is that this cost was $1 billion to $2 billion; amortized, some $300 million to $400 million of it was spent on Clementine.

—Saunders Kramer
Gaithersburg, Maryland

Correcting His Elders

I conduct tours of the National Museum of Naval Aviation in Pensacola, Florida, where the Stearman that George Bush flew in World War II is on display. Recently, one of our visitors told me that the youngest U.S. Navy aviator in history was not Bush, as you state in "Back to the Basics" (Oct./Nov. 1994), but a Captain Charles S. Downey.

C.C. Wheeler
U.S. Navy (ret.)
Foley, Alabama

Editors' reply: We contacted Captain Downey, and he told us that when he was commissioned as a U.S. Navy aviator, he was 13 days younger than Bush had been. He also sent a copy of a letter Bush wrote him in 1986 that reads in part: "As an old guy, I salute you young kids who were a 'younger 18' when you got your wings."

Corrections

Aug./Sept. 1996 "Who Made the Mustang?": (1) The Doolittle raid on Tokyo was made in 1942, not 1941. (2) The first Merlin engine installed in the Mustang III, P-51B and C models, was rated at 1,670 horsepower; 1,650 was its displacement in cubic inches.

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Up Ship!

For anyone who delights in flying low and slow, whose eyes grow misty at the memory of the great dirigibles, here's glorious news: Zeppelin airships are returning. The firm with the name long synonymous with lighter-than-air flight had left the business soon after the 1937 demise of the *Hindenburg*. Zeppelin shifted its metalworking talents to the production of aluminum cookware and other earthbound goods. But now, after a hiatus of more than a half-century, airships are once again under development in Friedrichshafen, Germany.

That does not mean that behemoths bearing the name "Zeppelin" will once again traverse the oceans. Program manager Klaus Hagenlocher explains that the new aircraft, with their ability to hover quietly and stay aloft for long periods, are designed to fill "a niche between helicopters and airplanes." Sightseeing, ground surveillance, and atmospheric research are among the intended applications.

ZEPPELIN LUFTSCHIFFTECHNIK GMBH

Blimps, which are non-rigid gas bags, do some of that already, and the first of the new Zeppelins will be about the size of the Goodyear blimps. But the Zeppelin NT (for New Technology) features design innovations to overcome many of the disadvantages of current lighter-than-air flight. Twin Lycoming engines amidships can swivel, providing vectored thrust down, up, or straight ahead. Two more engines are mounted at the very rear, one vectored and one fixed in the lateral position like a helicopter's tail rotor. This arrangement is supposed to give the NT unprecedented maneuverability, so it can land without the large ground crew required for earlier airships.

On the inside, the NT is a hybrid, with elements of both rigid and non-rigid construction. Like a blimp, its shape is to be maintained by internal gas pressure. But there are to be several gas bags, not just one. And there is a rigid frame, made of an aluminum alloy and carbon fiber composite, forming a series of triangles attached to three longerons that run the length of the ship. The two pilots will have the latest in "glass cockpit" technology as well as fly-by-wire flight controls.

The NT project has suffered delays, but last July Zeppelin was able to unveil the framework of a prototype. The goal now is to drape that skeleton with its multi-layer envelope by the end of the year and inflate it with helium in time for presentation at an airshow in Friedrichshafen next April. The current model accommodates 12 passengers, and if it proves successful, larger versions that can hold 42 and 84 passengers may be attempted.

Still, airships are a risky venture. Westinghouse has also been developing advanced designs, but after a hangar fire destroyed its only prototype last year, the company stopped work on the program and may sell off its remaining airship assets. Zeppelin claims to have orders "almost finalized" for six NTs, priced at about $7.5 million each, but it declines to name the prospective buyers. Some skeptics, even in airship-crazy Friedrichshafen, question whether there will be enough customers to keep the project going. "It's not just the purchase cost," says one local expert. "To operate an airship you need hangars, mooring masts, a helium supply. That's infrastructure, and it's very expensive."

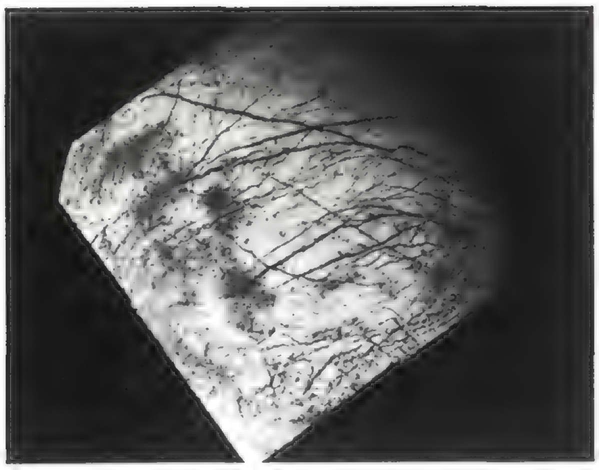
—*Lester A. Reingold*

UPDATE

Departures

Former North American Aviation aerodynamicist Ed Horkey ("Who Made the Mustang?" Aug./Sept. 1996) died of a heart attack last July 25 in Phoenix, Arizona. He was 80.

Sir Frank Whittle, co-inventor of the turbojet engine ("Gentlemen, I Give You the Whittle Engine," Oct./Nov. 1992), died of cancer last August 8 in Annapolis, Maryland. He was 89.



JPL

Dowsing on Europa

Science fiction writers have long used Jupiter's moon Europa as a setting for alien life, based on speculation that an ocean lies beneath the satellite's cracked, icy crust. And where there's water, the thinking goes, there might also be life. Now scientists are inching closer to confirming at least the ocean part. Pictures returned last summer by the Galileo spacecraft suggest that the moon may in fact have liquid water—or perhaps mushy ice—underneath its scratched-up shell of a surface.

"In some areas the ice is broken up into large pieces that have shifted away from one another," says Galileo scientist Ronald Greeley of Arizona State University. "This shows the ice crust has been or still is lubricated from below by warm ice or maybe even liquid water." The pictures also show small spots, or pits, in Europa's surface, which could be dormant or even active geysers.

Galileo will get even closer looks over the next year. The pictures taken in June show details as small as a mile across, but close flybys on December 19, 1996, February 20, 1997, and November 6, 1997, will resolve features as small as 65 feet.

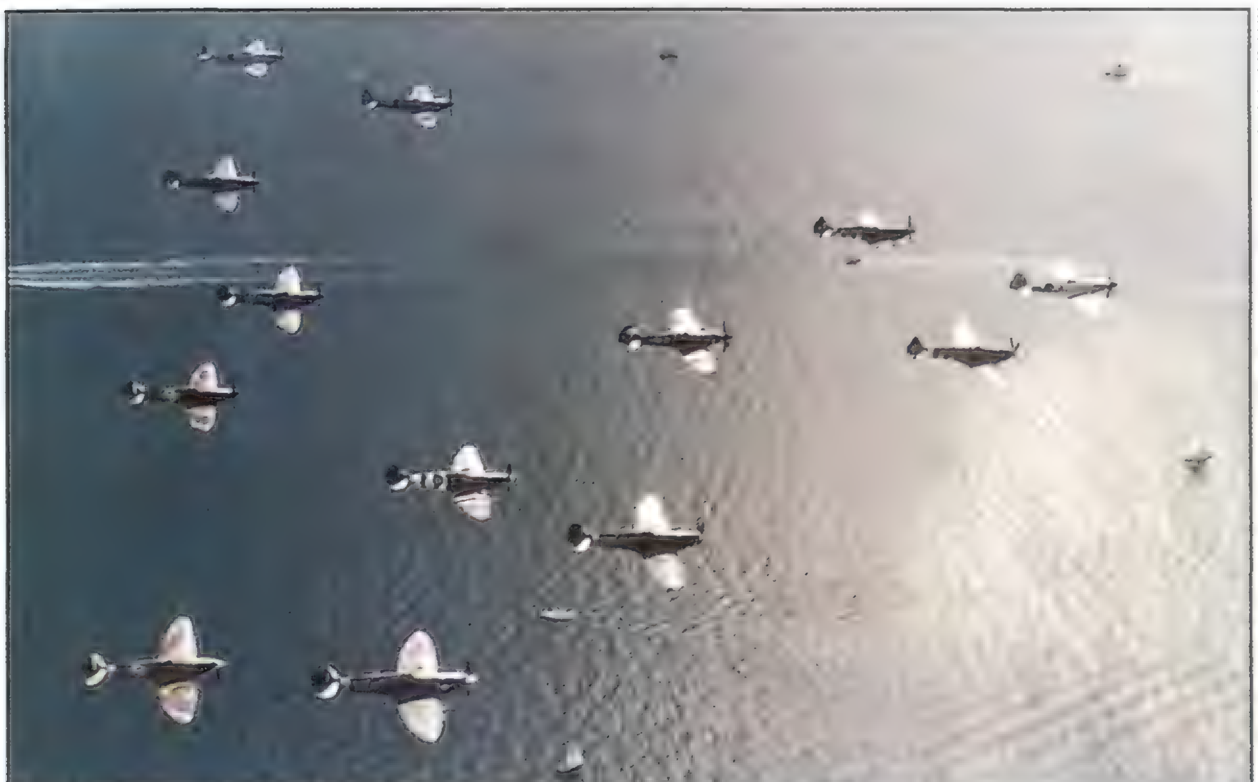
Even better, NASA has begun thinking about extending the Galileo mission beyond its planned November 1997 shutdown. If the agency can scrape together $10 million to $15 million for an extra two years of mission operations, the spacecraft will make several more swings past Europa, returning pictures with resolutions down to seven feet and covering parts of the moon that will go unobserved during the main mission. That might be enough, say scientists, to settle whether those strange spots are geysers, craters, or something else altogether.

—*Tony Reichhardt*

NASM

ED STOKES/CHICAGOLAND GLIDER COUNCIL

Last July, in honor of Octave Chanute's 1896 experimental glider flights off the dunes at Miller Beach, Indiana, mechanical engineering students from the Rochester Institute of Technology in New York flew an updated version of Chanute's biplane glider at the site, where a memorial plaque commemorating the original 700-plus flights was unveiled. "We asked ourselves: If Octave Chanute were alive today, how would he go about building a hang glider?" says team member Peter Karpinski. Chanute's craft was constructed of wood and muslin; the five-member RIT team, which undertook construction for their senior design project, used aluminum and carbon fiber to produce a beefier glider that can bear a 400-pound load and four Gs. The replica is now on display at the National Soaring Museum in Elmira, New York, which sponsored its construction.



JOHN DIBBS/THE PLANE PICTURE COMPANY

England was in the grip of Spitfire Fever last spring as airshows across the country commemorated the 60th anniversary of the fighter's first flight, made on March 5, 1936. The city of Southampton, the home of the Spitfire, arranged a record-setting flyby of 13. "The evening before the show we had 12 Spitfires parked at Southampton airport," says airshow organizer Jeanne Frazer. "And at one o'clock on the day of the show, the last plane—the 13th—flew in after having completed a show across the Channel in France that morning." The May 5 flyby topped an Israeli Air Force demonstration of 11 Spitfires and a Burmese Air Force flight of 12.

UPDATE

Waterworlds

NASA's largest underwater training facility, built in 1968 at the Marshall Space Flight Center in Huntsville, Alabama, will close next spring ("Charlie and the Aquanauts," June/July 1993). A larger $32.5 million Neutral Buoyancy Laboratory is being constructed at the Johnson Space Center in Texas. "We'll keep it open to be sure JSC can handle the load," says Jim McMillion, Marshall's director of science and engineering. "If they can, we'll shut it down, drain it, and purge it to keep it safe." The facility was registered as a national historic landmark in 1985 and cannot be scrapped.

Housing by the Pound

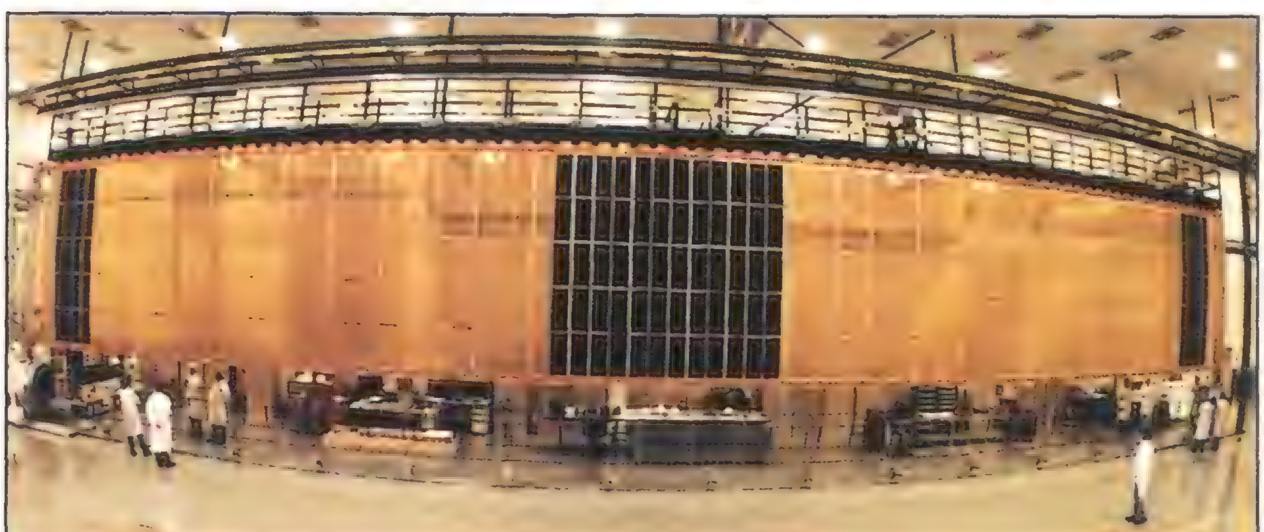
From Mississippi comes word that Benoit hairdresser Jo Ann Ussery has converted a decommissioned Boeing 727 into a home. The three-bedroom, one-and-a-half-bath airliner has a hot tub in the former cockpit, picture windows in place of the emergency exits, and an electrically powered retractable staircase in the tail. It sits on a wooded lot, nose overlooking Lake Whittington. "I just love my airliner," Ussery says.

"She really did an A-number-one bang-up job," says Richard Cordle, who sold Ussery her new home. Cordle works for the Memphis Group, an aircraft salvage operation that buys up played-out airliners for parts and sells the carcasses for scrap—or housing. In the 20 years he's been in the business, Cordle has sold at least 15 ex-airliners as dwellings, everything from a Lockheed Constellation to a 727. "Most folks use them for hunting and fishing cabins," he says. Including paying the scrap price of 15 cents per pound, charges for towing the craft to its final destination, and renovations, Ussery spent just $30,000 for her 12- by 120-foot house—as long as two trailer homes set end to end. "You couldn't build any kind of building anywhere near as good for three times the money," Cordle points out. "The wind won't get to it like it was a trailer," he adds. "Wind more or less rolls off it. Even tornadoes and hurricanes don't really affect it that much. There's no trouble with termites either."

Interested? At the moment Cordle has one 727 and five 747s on hand. "You'd have to weigh it and buy it by the pound, so a seven-four would probably run between $24,000 and $27,000," he says. "For that you get 4,800 square feet on the main floor itself, plus two parking garages [the cargo holds] and an upstairs too." They don't move as fast as the smaller airliners: A 747 is 62 feet tall and 240 feet long and weighs 360,000 pounds. "You can't pull it down the highway, and what bridge would you take it across?" Cordle muses. "There's a whole lot of people who come to look at one and scratch their heads, wondering how they'd get it home."

—*Phil Scott*

TOM KOSTER



RUSS UNDERWOOD/LOCKHEED MARTIN MISSILES & SPACE

A testbed for the international space station's power source, the Solar Array E-Wing is undergoing testing at Lockheed Martin Missiles & Space, located, appropriately, in Sunnyvale, California. A mast and massive blanket assembly will be extended and retracted dozens of times, and the individual solar panel circuits will be flash-tested with simulated sunlight. "The inspection process looks for mechanical defects and cracks in the solar cell filter covers," says Bob Bombardier, manager of manufacturing and test operation. "To a proton, a crack looks like the Grand Canyon, and because of the high proton density in low Earth orbit, a defective cell can be badly damaged and the power output of the arrays degraded." The space station will employ eight solar array wings, each 108 feet by 38 feet.

That's Entertainment!

THE KENNEDY SPACE CENTER VISITOR CENTER

CELEBRATES SPACE WEEK, JULY 16 - 23

WITH AN EXCITING SLATE OF EVENTS:

Grand Opening of Viking/Mars Probe Exhibit
Appearances and Signings by Apollo Astronauts Buzz Aldrin, Alan Bean
"I Dream of Jeannie" Star Barbara Eden

CORBIS BETTMANN

Spacewalks for the Common Man

Whether your contribution to the U.S. space program was exploring the moon or emptying wastebaskets, here's your chance to be remembered for generations to come. You can have your name carved into a brick in either of two walkways being paved to honor the thousands of people who have supported America's space-based adventures.

One brick path, the U.S. Space Walk of Honor, encircles a reflecting pond at Florida's Kennedy Space Center, in the shadow of the Space Mirror memorial to astronauts who were killed in the line of duty. The other, the U.S. Space Walk of Fame, lies on the west bank of the Indian River Lagoon, which separates downtown Titusville, Florida, from the launch pads where every one of the nation's piloted space missions began.

"We're trying to recognize the workers and the companies that have made the space program what it is over the last 40 years," says David Stewart, a former Titan booster engineer who organized a Project Gemini reunion attended by about 400 program veterans last July. They all "kicked back and relived old times," Stewart says, but they raised only a fraction of the $139,000 needed to pay for a monument that will be erected on the Space Walk of Fame next year. "We've got a real uphill battle here to get everything ready."

The monument will commemorate the 12 Gemini missions, two manned and 10 unmanned, which bridged Mercury and Apollo by testing techniques for lunar flight. The Space Walk of Fame already features a donated replica of the Project

Mercury monument that has stood since the 1960s at Cape Canaveral Air Station's Complex 14, the site of the Mercury Atlas launches. Bricks laid into the base of that monument bear the names of engineers and others who worked on the Mercury program.

On the east side of the river, the Astronauts Memorial Foundation and the Florida chapter of the NASA Alumni League are selling bricks to raise money for space-related scholarships and education projects. By this time next year, they expect to have paved the Space Walk of Honor with 22,000 bricks, each inscribed with the name of a person who has participated in the space program. Tourists at the Kennedy Space Center will use a computerized kiosk to punch up a blurb about each individual and the precise location of his or her brick. Among the first 100 inscriptions are the names of Apollo 13 astronauts James Lovell, Fred Haise, and Jack Swigert.

Immortality isn't cheap. A brick in the Space Walk of Fame costs $100; one in the Space Walk of Honor is a relative bargain at $75.

—Beth Dickey

UPDATE

Mars' Mysterious Meteorite

The 4.5 billion-year-old Martian meteorite Allan Hills 84001 ("The Mars Mission to Earth," Aug./Sept. 1995), discovered in Antarctica in 1984, is stirring up the scientific community as well as laymen around the world. Last August scientists from NASA and three U.S. universities announced that they had discovered carbonate globules in the four-pound rock and organic molecules —polycyclic aromatic hydrocarbons, or PAHs—nearby that may have been deposited by primitive life-forms, as well as tube-shaped structures 1/100 the thickness of a human hair that resemble fossilized bacteria. Everyone from President Clinton to Carl Sagan jumped into the fray, professing varying degrees of belief that the findings suggest past life on Mars. NASA head Dan Goldin has invited worldwide independent inquiry and will make samples available to qualified researchers around the world.

A Day of Sorrow

On a mild evening last February, Mayte Greco, a 36-year-old commercial pilot, greeted me in Miami's historic Art Deco district with a kiss and a gift. She was slim, spoke with a slight Cuban accent, and looked hip in her black jeans, black bodysuit, and thick-heeled shoes. I'm a photographer at the National Air and Space Museum, and I'd come to Miami to photograph Greco for an upcoming book and Museum exhibit, *Women and Flight*, which will feature portraits of 36 women aviators. Sitting at an outdoor cafe, we looked over some of my photographs of these women, and it was apparent that she didn't know many like herself.

The next day I went to the Opa-locka airport to photograph and interview Greco. She arrived late, having spent the night at the hospital with her three-year-old son, who was running a high fever. She looked exhausted, but her face lit up when she began to talk about Cuba, her desire to go back, and most of all, her love of flight.

"I knew I wanted to fly airplanes since I was six years old," she said. But her father did not think flying was a proper pastime for a good Cuban girl, so in 1975, 16-year-old Greco had to begin flying lessons in secret. Her father found out, and on one occasion, while on final approach for landing, she realized that the man standing in the middle of the runway was her disapproving dad. But she would not be dissuaded, and today she owns and operates Wings Air Charter, which ferries passengers from Fort Lauderdale to Great Harbor Island in the Bahamas. Greco also serves as a volunteer pilot for Brothers to the Rescue, which searches for Cuban refugees trying to make it to American shores and delivers supplies to a Cuban refugee camp in the Bahamas.

Greco is a founding member of the organization along with group leader Jose Basulto, a veteran of the Bay of Pigs invasion. In 1990, seeking some adventure, they decided to look for Cubans escaping on rafts. Their first few flights were uneventful since they flew too high over the ocean, but once they descended to a lower altitude they started spotting rafts.

Greco told me stories of rafters coming over on inner tubes, styrofoam, and anything else that would float. From her low-flying aircraft, she has seen rafts with babies aboard, passengers dying of thirst, and sinking rafts surrounded by sharks. "Usually the rafter's feet start to rot away because they leave them in the water too long, trying to keep cool," she says. "They are in the water sometimes for six days with no water or food. I think the sharks can sense the decay and are attracted to the rafts." During one flight she threw her own lifejacket out of the airplane window to a drowning Cuban. The relief organization tries to drop enough water, food, and lifejackets to keep the rafters alive until the U.S. Coast Guard can pick them up.

At the Brothers to the Rescue hangar, I asked a worker to open the large doors wide, which let in enough light to take photographs. Inside it was quiet. Greco and I moved a few of the airplanes around. She told me that the light blue Cessna 337 behind us was Basulto's and that he didn't like anyone touching it ("It's his baby," she said). On the tail was the group's logo: a Cuban flag, a seagull, and a man in a boat waving his hand. I posed her in the cockpit of another Cessna 337, a blue and white one (right). I asked her to think of her searches for rafters, the time she found a father and his two sons in a canoe, or when she first spotted a baby. We photographed until we lost the light, then agreed to meet the next day for a session with her five children.

In the late afternoon, Greco showed up at the Opa-locka airport with two carloads of kids. The shot I had in mind was Greco with her children—ranging in age from three to 16—running and playing. After we finished, I was invited back to their house in Coral Gables for dinner; afterward, we would meet Basulto and his wife for coffee in Little Havana.

CAROLYN RUSSO (2)

The girls fought over who would ride up front in their mother's car. I followed behind. I noticed that Greco was on her cellular phone all the way home. When we reached her driveway and the kids got out of the car, I was relieved to see that they hadn't hurt one another.

"How is everybody doing?" I asked jokingly. Greco's 14-year-old looked at me sternly and said, "Not good. Two planes were shot down." Greco was still in the driver's seat, crying.

Inside her waterfront home an elegant dinner was waiting. The table had been set with candles, white linen napkins, small glass bowls filled with fresh flowers, and a buffet of lamb, fried plantains, beans, rice, and yucca. The phone was ringing constantly. There was no word yet on which of the Brothers were flying the two aircraft that had been attacked. (We would later learn that they had been flying in international airspace when two Cuban MiG-29s shot them down without warning.) I called my family to let them know I was not aboard either of the downed aircraft, an opportunity I would have accepted had it been offered. Greco, still crying, welcomed me to eat dinner and apologized that we wouldn't be able to go out for coffee afterward.

The news was out that Basulto, who had been part of the mission, was alive and that he would hold a press conference at the Opa-locka hangar in half an hour. I asked if I could tag along.

Heavily armed police stood outside the hangar, as well as dozens of reporters and a large crowd of Cubans yelling and holding signs that read "Kill Castro." One of the Brothers met us in the parking lot and escorted us inside.

Even though the hangar was filled with people, it somehow seemed emptier than the day before, when I had photographed Greco. Seated around tables were the grieving families of the four crew members who had been shot down, as well as many of the Brothers. The sobbing young woman sitting on the floor below an "Hermanos al Rescate" banner was the girlfriend of one of the missing pilots. The parents of another missing Brother sat quietly on a raft. I tried to make small talk with them, telling them where I worked. They said they had been to the National Air and Space Museum with their son.

Everyone was waiting for Basulto, who was answering questions for the FBI and other federal agencies. The crowd outside was becoming frenzied, chanting louder in protest of the attack. The Brothers in the hangar talked quietly, reassuring each other that Basulto had been flying over international waters.

Finally he came through the back door. It was obvious he had been crying. He asked the relatives of the missing pilots to step outside. There he confirmed that two aircraft had been shot down and that all on board were presumed dead. Soon all you could hear was weeping. The Brothers remaining in the hangar stepped outside to gather around the families. Together they held hands, huddled in prayer.

Basulto went back to the waiting crowd and began the press conference. Had they violated Cuban airspace? Why did they deviate from their original plan to fly to the Bahamas? How did his aircraft alone escape attack?

After the press conference, Greco left to pick up her daughters at a movie theater. I decided to hang around and meet up with a photographer from the *Miami Herald*. It was then that I realized why the hangar seemed so empty. The blue and white Cessna I had photographed Greco in yesterday was missing. It had been shot down.

—*Carolyn Russo*

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700, Mon.–Sat., 9 a.m.–4 p.m.; TTY (202) 357-1729.

October 2–23 1996 Smithsonian Lectures on Astronomy Series. Einstein Planetarium, 7 p.m.
- Oct. 2, Smithsonian Follows the Sun: From Solar Constant to SOHO. Shadia Habbal, Smithsonian Astrophysical Observatory.
- Oct. 9, From MMT to Keck and Beyond: The Renaissance in Large Optical Telescopes. Fred Chaffee, W.M. Keck Observatory.
- Oct. 16, The Cool Sky: Infrared and Submillimeter Astronomy. Paul Ho, Smithsonian Astrophysical Observatory.
- Oct. 23, From Einstein to AXAF and After: Exploring the X-Ray Sky. Harvey Tananbaum, Smithsonian Astrophysical Observatory.

October 3 G.E. Aviation Lecture. Brigadier General Charles E. "Chuck" Yeager, USAF (ret.), returns to share highlights of his colorful and history-making career. Free tickets will be distributed on a first-come, first-served basis at the theater box office beginning at 5:00 p.m. Langley Theater, 7:30 p.m.

October 7–28 "On the Wing: Animal Flight." Smithsonian experts on birds, bats, and insects will explain how these creatures fly. Oct. 7, Bird Flight; Oct. 14, "C'mon Geese" video; Oct. 21, the UltraGeese Project; Oct. 28, Insect Flight. Gallery 109, noon.

October 26 & 27 "Wings & Things" Open House. Get a look at more than 150 rarely seen airplanes and spacecraft in the Museum's collection. Paul E. Garber Preservation, Restoration, and Storage Facility, Suitland, MD, 10 a.m. to 3 p.m.

November 7 G.E. Aviation Lecture. Alexander Zuyev will recount his experiences as a fighter pilot in the former Soviet Union. Langley Theater, 7:30 p.m.

Family Overnights in the Museum. You and your family can sleep over at the National Air and Space Museum. Bring your sleeping bags and enjoy such activities as making paper airplanes, viewing IMAX films, and participating in science demonstrations. Each overnight includes dinner in the Flight Line Cafeteria, a continental breakfast, and overnight parking in the Museum's garage. Recommended for children ages 10 to 14 accompanied by their parents. Oct. 5, How Things Fly; Nov. 16, A Few of Our Favorite Things. For more information call (202) 786-2106.

National Air and Space Society

As a member of the National Air and Space Society, your support will help the Museum's efforts to build an extension at Dulles International Airport, which will display such artifacts as an SR-71 Blackbird and the space shuttle *Enterprise*. To receive additional information, call (202) 786-2643 or write to the National Air and Space Society, NASM, Room 3520-B, MRC 310, Washington, DC 20560.

Redemption

It's funny the way the mind is adept at blocking out bad memories. I don't remember who called me at home that Sunday afternoon, I don't remember the exact words the caller used, and I don't remember what I said to my wife or my friends as I put down the phone and turned around, stunned. But I do remember needing to close myself in my bedroom for a half an hour or so, and I remember I had tears in my eyes.

In my 17 years as NASA's chief scientist on the Hubble Space Telescope program, I've known incomparable highs and wrenching lows—experiences that I've compared to excursions to Mt. Everest and Death Valley. One of the highest had come just two months before that June 1990 day, with the launch of the telescope. Now I was about to face one of the very lowest.

In the period following the launch, a series of minor problems had cropped up with the telescope—not unexpected in a spacecraft that has hundreds of thousands of parts and was built by 10,000 people. The first occurred two days after launch, when the solar array got stuck during deployment. Then we had some difficulty calibrating the star trackers—optical devices that find known stars, providing the satellite with a navigation reference—and it took a while to find our first star and learn in which direction we were pointing. We found the solar panels jittered every time they passed from sunlight into Earth's shadow and vice versa, creating a problem in holding the spacecraft steady during long exposures. And we had difficulties with the communications antenna.

Many of these problems were resolved by the end of May. Nonetheless, this was when a phrase I have come to hate, "Hubble Trouble," first appeared (and gave rise to the unspoken rule that we'll never again give anything a name that rhymes with "trouble").

In May we also began to try to focus the telescope. It was taking much longer than expected. The optics expert who was attempting the calibration would do a test and take a picture: *Nope, still out of focus; well, let's move the mirror this way, take a picture—nope; well, let's try it this way....* I remember one depressing day in early June when I began to realize that we might have a serious problem. The optics expert had done some more detailed calculations and was convinced that we'd finally got the right settings. There were about six of us around the console waiting for the picture. And then there it was, terribly out of focus—a bright spot in the middle, but surrounding it, a fuzzy halo. I'll never forget the look on the optics expert's face.

NASA VIDEO (2)

"It was the worst day of my career": The author announces at a 1990 press conference that the Hubble is seriously flawed.

We continued to try to focus through the rest of June, but people were more and more convinced that something was wrong. Still, nobody wanted to believe it.

Then came that phone call. I was told that the final data were in, and that I'd better come to Goddard to look at it. (NASA's Goddard Space Flight Center in Greenbelt, Maryland, is the control center for the telescope.) The problem was something called spherical aberration: Light reflected from the telescope's main mirror did not focus at one point as it should but over a range of points, causing a fuzzy image. It was a serious problem and a quick fix was way beyond our powers. We needed to meet and prepare to brief NASA management and others.

Right away, we decided to go public with the information as soon as possible. Only two days after concluding that the telescope had a problem we could not correct from the ground, we held a press conference. I had the unenviable job of getting up in front of the press and telling them how this problem would affect all the wonderful science we had promised.

By pure coincidence, the telescope's science working group had begun a two-day meeting at Goddard that day. I prepared for my task by going around the room and asking the scientists: "What is it that you will be able to do, and what is it you won't be able to do?"

The principal investigator behind the telescope's Wide Field/Planetary Camera, Jim Westphal of the California Institute of Technology, was especially glum. He was in charge of what many thought was the most important instrument. The other instruments aboard were to perform tasks such as spectroscopy or astrometry, which, although producing critically important science, were sometimes a bit esoteric for the average person to understand. But the Wide Field/Planetary Camera was to deliver pictures, pictures the world wanted to see. From the depth of his despair Jim gave an honest response: His camera team would not be able to do any of its planned science program.

What neither Jim nor I had considered at that difficult time was the broad community beyond his team that would want to use the camera and, more importantly, the critical role that computer-assisted image processing would play in cleaning up the camera's pictures. Thus, in an effort to quickly go public with the news, we had reached a premature and overly negative conclusion about the camera's capabilities.

The press conference was held at Goddard just after lunchtime on June 27, 1990, and it was packed. Several NASA managers made opening remarks. Then I got my turn and—descending very rapidly to Death Valley—told the reporters exactly what the scientists had told me: that on the average we would probably be able to do only about 50 percent of the science we had planned. "Our telescope now has bad myopia," I said, a phrase I would read again and again in newspapers the next day. "It would be dishonest of me to say that the mood of the scientists is very happy right now. We're all frustrated, but no one is walking away from the program." It was the worst day of my career.

But we had an insurance policy, and I let the reporters know that as well. Several years earlier we had started building a backup Wide Field/Planetary Camera, a sensible step given the importance of the instrument. And we committed to go up with the space shuttle before the end of 1993 and fix the Hubble Space Telescope—or at least the Wide Field/Planetary Camera. By that time we also knew the error in the primary mirror: It was a perfect curve; just, by a missing two microns of glass around the edge—that's 1/50 the width of a human hair—the wrong curve. I knew we could install mirrors on the replacement camera that would completely correct for the flaw, just as glasses correct nearsightedness, and I told the journalists so.

The trouble was, while a few newspapers carried accurate accounts of the press conference, many others published reports that made it sound as if the telescope was dead and useless. I remember in particular one of the New York tabloids carrying the headline "Pix Nixed as Hubble Sees Double."

It became a standing joke. Jay Leno joked about it on "The Tonight Show," and it was the subject of cartoons, like the one revealing that the real inventor of the telescope was Mr. Magoo. The public got the impression that the Hubble was worthless. People would come up to me and express their sympathy for my having to work on such a national disgrace—their words, not mine.

Generally I enjoy speaking publicly about my work, which is how I fell into the role of Hubble spokesman to begin with. Astronomy is interesting to people, and when you've got an audience that's attentive, it's fun. But the days following the press conference sorely tested that perspective. On an almost daily basis I led huge press telecons: 70, 80 reporters hooked up from around the world who fired out questions on the order of "When did you stop beating your wife?"

In early August I was still slogging through Death Valley when Riccardo Giacconi, the director of the Space Telescope Science Institute, called my boss Charlie Pellerin—the director of the astrophysics division at NASA headquarters—and me and said, "You guys, you've got to see this." The Hubble had photographed something theorized a decade or so ago to be the most massive star in the universe: R136a in the Large Magellanic Cloud. Subsequent higher-resolution ground observations had showed it to be a few massive stars. But the picture—made with the very Wide Field/Planetary Camera once thought to be useless—revealed that R136a was actually a cluster of 60 or 70 fairly average stars. It was an important scientific finding. (Computer image processing had removed much of the "fuzziness" the flawed mirror created around objects.) This called for another press conference.

Held early the next week at NASA headquarters, the conference was well attended, though not so packed as the bad-news conference. I started by saying, "I'm here to tell you the Hubble Space Telescope is not dead. The Hubble is alive." The next day the headline above a *Washington Times* story echoed my words: "Hubble Is Alive." I knew then I was about halfway out of Death Valley.

I probably passed sea level around the first part of 1991 at the American Astronomical Society meeting. A lot of Hubble data were released there and the press picked up on it pretty well. Throughout the year, we continued to release a lot of good data.

But then all of us on the Hubble team hit a plateau. We were getting nervous about the upcoming servicing mission, scheduled for a space shuttle flight a little over a year from then, in December 1993. We were committed to do it on cost and on schedule—something the Hubble had never been known for. Furthermore, we had experienced several more mechanical failures, and as the servicing mission drew closer, it became apparent that no less than five spacewalks of six hours each would be required to make all the repairs. It looked as if this would be the toughest shuttle mission ever flown.

We were well aware that the Hubble was an expensive program and that if the servicing mission wasn't successful, Congress probably would not continue to fund the telescope. Also, funding for the space station was hitting some snags in

Joy and relief came in the middle of the night three and a half years later, when scientists at the Space Telescope Science Institute watched the repaired Hubble's first image appear on a computer monitor.

Congress, and some in the media pointed out that if a repair mission that relies heavily on spacewalks fails, who was to say efforts to build the space station—also dependent on spacewalks—wouldn't fail as well? So suddenly the space station became tied to the success of this mission. Then people started to say that maybe the whole future of NASA was at stake as well.

By the time we got down to Kennedy Space Center in Florida for the launch, people were pretty tense. The night of the launch came, and a bunch of us gathered at the press site to watch. The wind was blowing at about 30 mph and it was cold, and as we stood beneath the stars, I knew in my heart the shuttle wasn't going to get off that night. Sure enough, the launch was scrubbed due to high winds.

Yet the night offered me a scrap of solace. As I looked up, I saw the Hubble moving east in the pre-dawn sky. (You can see the Hubble anywhere below about 30 degrees north; it's as bright as some of the brightest stars.) It was comforting to see the goal of all this effort so serenely sailing by, 356 miles above.

The next night the countdown went all the way, the night sky lit up, and the shuttle started to rise off the pad. I stared at it until it became a star, a fainter star, and then finally winked out.

At about 5 a.m. we flew to Houston to watch the mission unfold. A thousand things could go wrong. But as it turned out, all the practice, all the troubleshooting of the past year, left those of us on the senior Hubble management team with effectively nothing to do. Everything went like clockwork. On the fifth day of the mission, astronauts Story Musgrave and Jeff Hoffman installed the replacement camera, and there was a big release of tension because that accounted for half of the telescope's planned science. The next day, astronauts Kathy Thornton and Tom Akers installed the COSTAR, an optical device that would restore clear vision to three more of the Hubble's scientific instruments.

By the mission's end I was about 100 feet below the peak of Mt. Everest. But there was still one thing left to verify: Did the fix work? Did the camera work? Did it take pictures that were sharp and clear? We had estimated that it would take six to eight weeks to find out for sure, but about two weeks later, John Trauger, the leader of the Wide Field/Planetary Camera-2 team, paged me. He said, "Ed, looks like we might be able to get a picture down on the 18th." It was 10 years to the day after I had proposed the concept of a backup Wide Field/Planetary Camera to management.

That evening I drove from my home in Annapolis to the Space Telescope Science Institute in Baltimore. The whole Wide Field/Planetary Camera-2 team was there. The first picture was due to come down around 1:00 a.m. (It seems that everything that happens on Hubble happens in the middle of the night.) Again, I found myself staring at a computer screen in a room full of tense and hopeful people. What if we got the prescription for the corrective mirrors wrong? What if the camera had been installed out of position and was beyond its range of focus?

We had good reason to question everything: If you had asked the scientists and engineers on the Hubble project the night before launch in 1990 to write a list of the top 100 problems they thought might occur, not one of those lists would have included a misshapen mirror. That was too outlandish. We had been burned so badly by not anticipating what happened then that no one was letting his or her guard down now.

The picture came up on the screen. There was a moment of silence. People started moving closer to the screen. On it was a very tiny, bright dot—the main target star—exactly as it should appear. No halo. No spikes of light coming out of it. No fuzziness. Just myriad faint but sharply focused stars all around it.

There was a pause of about three seconds, although it was the longest three seconds I've experienced, and then a cheer went up. I remember thinking, *My God, the nightmare of "Hubble Trouble" is over.*

In the weeks to come we confirmed that the COSTAR was also working, thus ensuring that all four of Hubble's main scientific instruments could now do nearly all the science originally planned. And during the winter of 1994, the science really started to flow, with front-page stories of the Hubble's achievements becoming a regular event—and a measure of redemption for me and the entire Hubble team.

If I sound obsessed with media coverage, it's because I've always used it as a measure of the public's interest in our work. If news of the Hubble's discoveries makes the front page of the *New York Times* or the cover of *Time* magazine, it must be fairly interesting to the public.

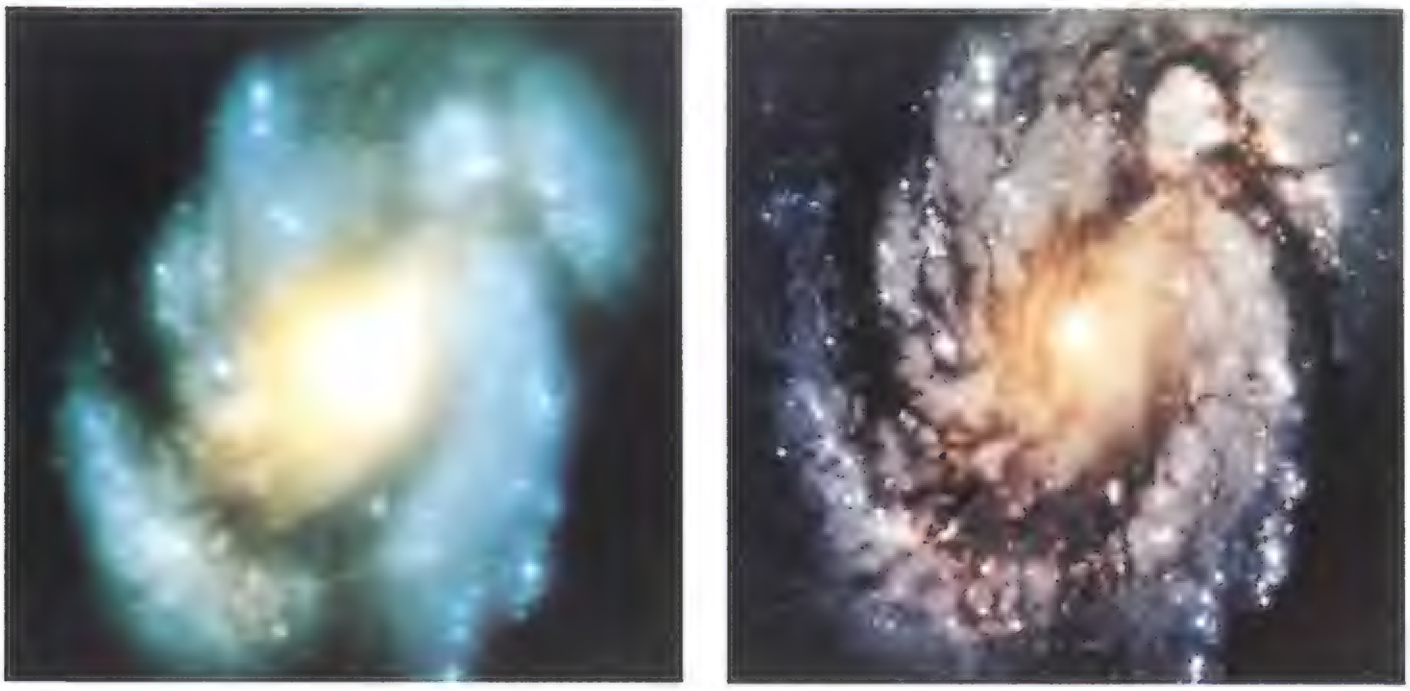
Another sign of that interest is that when I wear my Hubble team jacket, somebody will inevitably approach me saying, "Great job. Boy, that stuff is really good," a tremendous contrast with five years ago, when they expressed their sympathy or gave me dirty looks.

I knew we really had it made, though, when the cartoons turned our way. About a year ago, one came out that's now hanging in Hubble project offices all over the country. It shows a boy and his dad in a telescope store. The dad is pointing to what looks like a nice telescope but his son has tears in his eyes. Looking up at his father, he's saying, "Couldn't we get a Hubble?"

So the transition was complete, from what some called a national disgrace to a national measure of excellence in less than five years. It's been quite a time. I use that cartoon in all my public lectures. I use it right at the end.

—Edward J. Weiler, as told to Karen Jensen

Two images of the core of a galaxy 50 million light-years away—the left taken just before the Hubble's dramatic 1993 repair mission, the right just after—show the increased clarity of the telescope's vision.



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SECOND-HAND SMOKE

In 1948, as a flightline crew chief at Douglas Aircraft in California, I worked on the U.S. Navy's AD-1 Skyraider. The El Segundo factory at Los Angeles airport was churning them out, and to accommodate the production schedule, many simple, practical methods of testing aircraft systems were devised.

The Skyraider had an unpressurized cockpit, and there was a possibility that carbon monoxide fumes from the engine's short exhaust stacks could gain entry and asphyxiate the pilot. We needed to test for adequate sealing of the cockpit, and we did it not by putting the airplane into a smoky chamber and seeing what leaked in but by filling the cockpit with smoke and checking what leaked out.

The device we used was known as the Hookah. A real hookah is a Turkish pipe equipped with a jar of water. One sucks on a hose that draws smoke from the pipe's bowl through the water, then into the mouth. The Douglas Hookah, which was mounted on a big cart, had a large blower driven by a 220-volt motor, a draft-controlling door, and a large flared bowl filled with tobacco products.

This tobacco was of questionable quality. When burned, it produced noxious white smoke that stank to high heaven and made everyone within a hundred yards cough and gag. Imagine yourself downwind of a burning cork forest that had touched off an inferno at a fat rendering plant after first burning down a tire factory. However, these foul characteristics were what made it so desirable for the cockpit seal tests.

The operation began by filling the big bowl with about five pounds of the dreadful tobacco and starting the motor. The blower drew air, which hissed nastily as it rushed through the shredded stuff.

A mechanic lit the concoction, and as the fire spread through the tobacco, the air-draft door was adjusted. The Hookah sighed a little, the tobacco began glowing bright orange, and the thing started puffing maniacally. Then a large hose on the base of the bowl was inserted into the cockpit air inlet in the carburetor air scoop on the engine cowling and taped down. The canopy quickly filled up with smoke and the cockpit interior disappeared in a milky white haze.

After that, things got positively droll. One man would get up on one side of the cockpit and another on the opposite side, then both would put their noses on the joint between the fuselage and the canopy and slide along the joint, sniffing. A third man would sniff-test the areas immediately below the cockpit. If they could smell the nauseating smoke, we had a reject. If they couldn't, we called an inspector to sign it off—fast—for the Hookah spewed smoke like a union hall full of poker players. (The test pilots who first flew these airplanes turned green from the lingering

KEVIN J. RECHIN

stench, which took forever to dissipate.)

One night we were prepping the Hookah and made the mistake of calling the inspector too soon. He arrived to find us still diddling around, trying to get a fire started in the bowl. The tobacco was wet and was resisting our efforts. The inspector stood around, looking at his watch impatiently. Finally, seeing that we were just whistling Dixie, he stomped off.

We gave up on the wet tobacco and found a dry but nearly empty sack of the stuff. We managed to clean out the mess of wet tobacco in the Hookah and load up the meager portion of dry leaves. In short order we had a fire going and the requisite amount of smoke. A sniffer slid along the canopy-fuselage joint, then went into the hell hole below the cockpit and sniffed again. Okay! Hot dog! He sent someone running for the inspector.

The inspector took his sweet time returning. We watched helplessly as the Hookah happily puffed its dwindling supply of tobacco. We had to improvise.

All eyes went to the chain link fence between the flightline property and Imperial Highway, a catch-all for debris blown by nature and propellers. Someone was sent scurrying toward the fence with a bucket to harvest some of this bounty. Meanwhile, the inspector was walking purposefully across the flightline. If we weren't ready for him this time we'd never get him to come back.

The scavenger returned in triumph with the bucket full of dried weeds, old milk cartons, rubber heels, soiled shop rags, plastic tubing fragments, and other flotsam and jetsam, all of which we stuffed into the Hookah's nearly depleted maw.

The smoke in the cockpit turned an alarming and malevolent green. Bursts of colored flame were erupting in the bowl. The smoke was almost viscous, evident by the irregular whine of the blower motor, and the air draft door was making dreadful wheezing sounds.

We urged the inspector to hurry and check the hell hole, then get up on the wing and check the canopy joint before the Hookah self-destructed. Though dubious of our smoke source, he performed the inspection and, satisfied, signed off on the test.

We had to use fire extinguishers to put the Hookah out of its misery. When we opened the canopy the stench was appalling. Later, this Skyraider did indeed make a test pilot sick, along with those of us who had to get in it to run the engine. We tried everything to rid the cockpit of the smell. I'm sure it was still present to some degree when the airplane was finally delivered to the Navy, but by then we had grown accustomed to it.

—O.H. Billmann

SEARCH AND DESTROY:

Unsafe parts are out there. It's up to industry, law enforcement, and the FAA to find them. But can they?

Safeguards against counterfeits include inspecting parts when they arrive at repair facilities (right, bottom), quarantining them if discrepancies are found (top), and reporting bad parts to the Federal Aviation Administration. Many repair stations also mutilate parts that have passed their service lives to prevent their return to the system (above).

THE WAR ON COUNTERFEIT PARTS

by William Triplett

Photographs by Chad Slattery

Like cops of every stripe, Harry Schaefer liked to think he knew what was happening in the world he patrolled. By the spring of 1991, Schaefer, a special agent for the U.S. Department of Transportation's Office of the Inspector General (OIG), had been wading through the muck of aircraft maintenance and repair scams for five years. Most of the cases he pursued as an OIG investigator targeted the isolated aircraft repair station or parts distributor selling substandard, illegal replacement parts. Then the FBI introduced him to Rodney Kostoff, the owner of Classic Aviation, an aircraft parts brokerage in south Florida. When Schaefer and a team of detectives executed a search warrant at Kostoff's business, Schaefer's world suddenly looked a lot uglier.

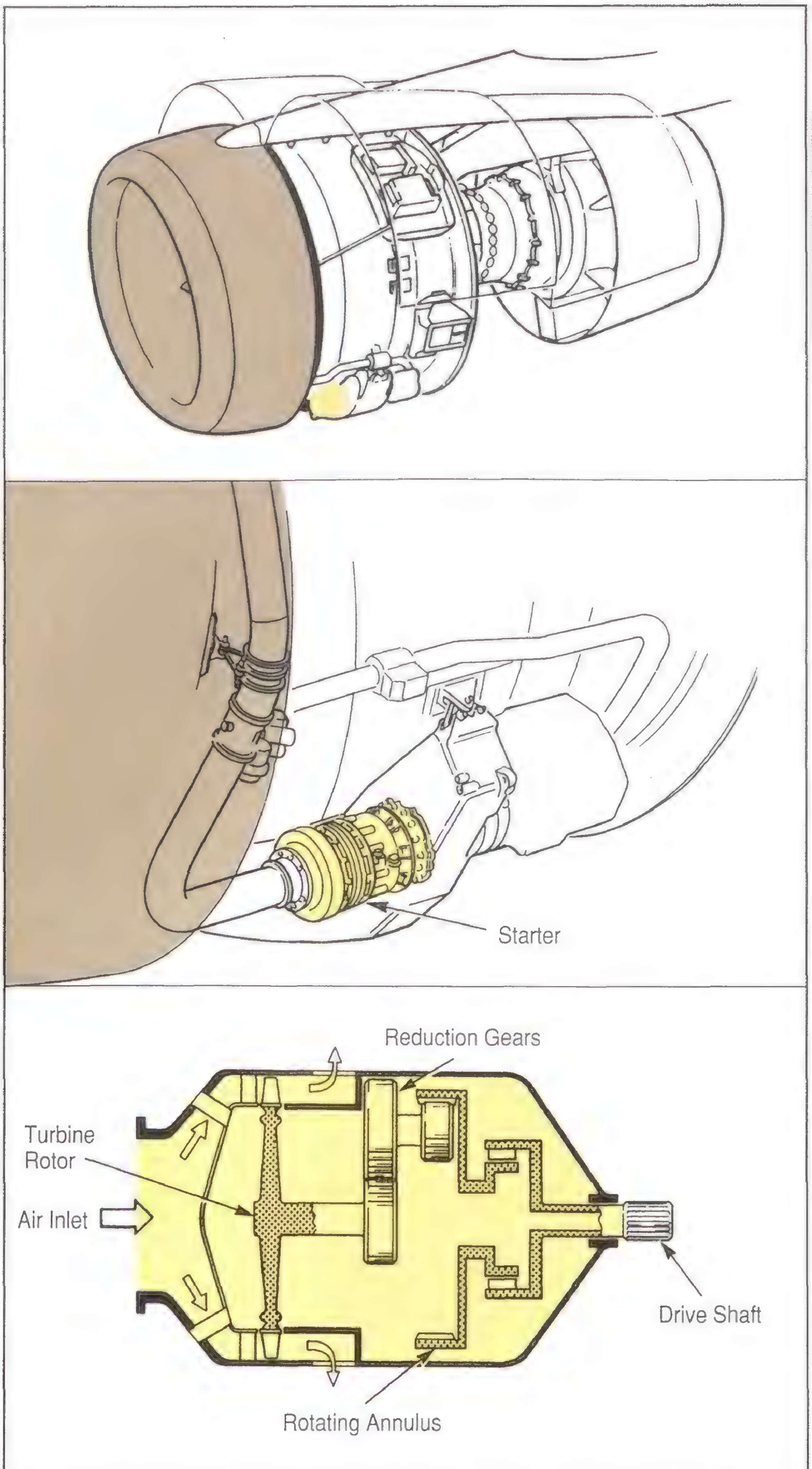
"We walked in and there they were, remaking gears that go inside engine starters," he says. The gears were broken; workers were welding teeth back on them. Others had welded broken starter housings, sanded and polished the welds, and painted over them to hide the work. Schaefer confiscated the gears, other starter parts, and complete starter units, which he later found to have been fabricated with substandard and repaired scrap parts. Kostoff had already sold 600 of the starters to repair stations for installation on commercial airliners and cargo carriers. The Federal Aviation Administration subsequently issued an Airworthiness Directive, the agency's most powerful tool, requiring operators of six types of Boeing and McDonnell Douglas airliners to track down the Classic Aviation starters and yank them. "Structural failures of the aircraft starter...could result in an in-flight fire or loss of control of the airplane," the directive read.

"That case had everything you could imagine," Schaefer recalls. "You had [Kostoff] making parts. You had him fixing parts. He subcontracted. He put false data plates on it. He did everything conceivable." But what really troubled Schaefer was what he discovered during the next two years of scrutinizing financial records and other paperwork to put together an indictment. Classic Aviation, he found, was merely the hub of an operation involving as many as 25 FAA-licensed repair stations, which had supplied and bought from Classic or had been hired by Kostoff to build starters (with parts supplied by him) and certify the work as an FAA-approved overhaul. The inspector general tried to build cases against five, but succeeded in indicting just one.

In November 1994 a jury convicted Kostoff on five counts of conspiracy to commit wire fraud and make false statements. The court fined him $6,000 and sent him to prison for 33 months. But OIG investigators came away feeling they had triumphed in only a small corner of a huge, dirty underground. "Classic Aviation really opened our eyes up," Schaefer says. Schaefer's boss at the time, then DOT inspector general Mary Schiavo, declared that investigating bogus aircraft parts would thenceforth be her office's top priority. With this spotlight trained on the issue, the number of suspect parts reported to the FAA began to increase. There were 52 reports in 1991, 362 in 1992, 239 in 1993, 411 in 1994, 317 in 1995, and 220 in the first half of 1996.

Although inferior aircraft parts have only recently become a priority for law enforcement agencies, they have plagued the aviation industry since at least 1957. That year the Flight Safety Foundation, a nonprofit membership organization, warned that "the stream of parts necessary for the maintenance and overhaul of aircraft and engines has become polluted [with counterfeits]. It is almost impossible to detect some of the phonies without extensive tests few of us are equipped to make."

Only manufacturers that have FAA approval can legally introduce safety-critical parts into the system. These businesses are either original equipment manufacturers that have had an FAA approval of design and production—like Pratt & Whitney, Boeing, or McDonnell Douglas—or companies that have secured an FAA approval to produce replacement or modification parts. At the other end, the FAA requires the airline or aircraft repair station to ensure that a part is airworthy per FAA standards before installing it on aircraft. In the middle, however, is a vast, unregulated sea of parts brokers and distributors—estimates range from 6,000 to 20,000, though no one knows



Classic Aviation was counterfeiting air turbine starters—small motors, driven by compressed air from auxiliary power units, that spin up engine compressors through a drive shaft. The starter is mounted on the engine, and a failure of its turbine wheel or gears could start a fire.

DRAWINGS COURTESY ROLLS-ROYCE INC.

for sure—who can buy surplus stock from approval holders and then sell to anyone interested (see "The Parts Pipeline," opposite). The lack of oversight of the middlemen makes the end users vulnerable, according to many in the industry and in law enforcement, and places an unfair burden of inspection on them.

In response to this burden, the airline industry and other aerospace contractors established in 1967 the Coordinating Agency for Supplier Evaluation, a nonprofit organization to evaluate airline maintenance, including individual members' procedures for inspecting parts. Since dues are expensive, CASE members tend to be the larger repair companies and airlines, but even most non-members conform to CASE standards. (Members will not do business with you if you don't.)

CASE is strict. It requires its members to audit suppliers and mutilate scrap parts. (The FAA announced last fall that mutilating scrap may soon be a requirement.) But since no one can be forced to join CASE or conform to its standards, crooks can carry on business as usual. The motive is strong: As a drug dealer told federal investigators not long ago, he switched from selling drugs to selling bogus parts because he "made more money and met a better class of people." The only protection is vigilance.

Along a wide boulevard on the north side of Miami International Airport, Greenwich Air Services occupies a behemoth hangar protected by a tall chain-link fence and two guarded checkpoints. Permanently displayed identification is required for employees; visitors must have appointments and be escorted at all times. But when 18-wheelers full of aircraft parts back up to the loading dock of Greenwich—the largest independent repairer of jet engines in the United States—the real security begins.

Receiving clerks are the first to unpack and inspect what are essentially an engine's internal organs. "We check to verify there is no obvious damage and that the [identifying] part number is with the part," says Roland Vadeboncoeur, who supervises receiving. The clerks then turn over the parts to Ben Matthews, head of Greenwich's seven

Parts inspection has an added dimension now that airlines have begun to farm out maintenance. Each of the engine parts from this Air South 737, for example, has its own inspection cycle and could have been repaired—or replaced—by any number of repair stations, which, in turn, use any number of parts suppliers.

full-time quality assurance (QA) inspectors, whose sole job is to ensure that the parts are the real McCoy.

Just a few feet in from the loading dock, using benches, tables, lights, magnifying glasses, and reference manuals, inspectors scrutinize the parts, looking for suspicious signs like a serial number marking. Some manufacturers hand-etch numbers; others stamp them. The QA inspectors have to know which supplier uses which technique. The inspectors also check the packaging—Is the manufacturer's logo in the proper position?—in addition to the accompanying paperwork. If satisfied, the inspectors scan the part's bar code into a computerized tracking system that will log (1) who approved the part for acceptance, (2) the part's exact location within Greenwich's 500,000-square-foot facility at any time, (3) the name of the last person to move it, and (4) the date and time he moved it. "Bogus parts have been a problem we've taken seriously for as long as I have been here," says Paul Streb, Greenwich's director of quality assurance for the last three years.

About 95 percent of the parts received will then go to the stocking area, a large fenced-in pen set more or less in the center of operations. Stock personnel check the paperwork to make sure everything is in order, then scan the bar code, and place the part on a shelf, where it stays until requested by a mechanic.

The remaining five percent—the usual amount that does not pass muster—is quarantined inside a fenced, padlocked area, inside of which stand three metal shelves, several feet wide and about seven feet tall. On this particular day all shelves are nearly full, representing about three weeks' accumulation of a variety of jet engine parts: tubing, fasteners, blades, vanes, spacers,

The Parts Pipeline

Manufacturers that operate with Type or Production Certificates—FAA licenses to manufacture entire aircraft. or the engines, propellers, and associated spare parts for aircraft—purchase parts from suppliers. The certificate holders, also called Production Approval Holders, at times have more parts than they need and sell the overages to parts brokers. This transaction is sanctioned by the FAA.

What is not sanctioned is the sale to a distributor by a PAH supplier—a subcontractor, for example, who makes turbine blades for a PAH engine manufacturer like Pratt & Whitney or General Electric. The difference is that the subcontractor is not required to implement an FAA-approved production inspection system as the PAH is required to do as a condition of its license. Parts sold by these suppliers, without written authorization from a PAH, are unapproved. Until recently, however, the FAA has not rigorously enforced the rule, covered by Federal Aviation Regulation 21.303, prohibiting the sale of these parts.

In February 1995, however, the FAA warned manufacturers of a change in policy: Any company manufacturing parts for installation on aircraft that did not already hold a production approval would have to apply for a Parts Manufacturer Approval, a license granted on the condition that the FAA approves the inspection process. For manufacturers that had not been supplying PAHs, the FAA would also have to approve the design of the part and ensure its repeatable production.

There are, however, exceptions to the rule. An owner or operator, such as an airline, is permitted to produce parts for maintaining or altering one of its own aircraft. These parts, however, may not be offered for sale to another owner or operator.

shafts, and wheels, to name but a few. "Most of it is a paperwork problem and will probably check out okay," says Matthews. Until it does, the part does not leave the quarantine.

In a corner on the far side of the hangar lies the other principal means by which bogus parts can penetrate the overall parts system. Engines in need of repair typically arrive at Greenwich as whole units, which mechanics then disassemble. Along an entire side of the facility a dozen or more reassembled engines of almost every type lie on trolleys like steel whales. "The mechanics get the first look at the parts inside and will tip the [disassembly] inspectors to any problems they might spot," says Paul Koppel, head of the disassembly section. The mission is essentially two-fold: to find any unfit or unapproved parts that, for a variety of reasons, may have been installed by either the client or another repair station, and to make sure that any legitimate parts that have worn out, been damaged, or passed a time limit on use are removed and properly disposed of.

"The first thing is to look for any obvious damage, like nicks, cracks, or scratches," says Frank Garcia, an inspector who is going over a high-pressure compressor. Next, to make sure components are wearing at the normal rate, he will check their dimensions against those listed in the appropriate reference manual. Any suspect part is placed inside a locked metal rack until a thorough review determines whether it can ever be used again. A materials review board—composed of parts experts and representatives of the client—will decide its fate. If everything checks out, the part can go back into service. If not, and if the client does not want the part back, Greenwich will transfer it to another secure area—the scrapping section, where parts are mutilated before being sold to scrap dealers.

If rejected parts aren't mutilated, they sometimes find their way back into the system. An air carrier, for example, once junked a used-up flap actuator only to unwittingly buy it back later. It had gone through a process called "stripping and dipping," the criminal's art of cosmetically treating a spent part and retailing it as new or fully reconditioned.

"It's time-consuming, expensive, and professionally embarrassing to have to go find and pull bogus parts from the inventory once they get in," says Streb. Which is why, in addition to the above measures, Greenwich periodically audits the brokers and distributors from whom it buys parts. "Know your supplier" is the catch-phrase: What it means is sending someone into the supplier's shop to pull parts randomly from stock and check the paperwork for full traceability. Whether a vendor will accept this as a condition of doing business is often the first indication of how reliable his parts are. "A reputable vendor will not object to being audited," Streb says. Neither, apparently, will a reputable repair station. Greenwich's clients—Federal Express, United Parcel Service, Continental Airlines, even some U.S. military customers—periodically send auditors into Greenwich's stock area to do the same thing.

Streb reports any part having a dubious pedigree or appearance—a Suspected Unapproved Part or SUP, in FAA parlance—to an FAA inspector who visits his establishment about once a month. Once a SUP report is filed, the FAA inspector notifies headquarters and launches a separate investigation into whether the part is in fact usable or illegal. This, at least, is the plan.

The FAA is the aviation industry's second line of defense against the pollution of the national parts inventory. The agency employs 1,571 airworthiness inspectors to verify that repairs are being done according to FAA regulations, which stipulate, among other things, that only approved, airworthy parts be used. Making sure that repairs conform to standards was easier when the airlines did more of the maintenance themselves. After the airline industry's 1978 deregulation, the airlines started contracting with independent repair stations as a way to cut costs. Today there are 4,900 FAA-regulated repair stations across the country. And, over the last three years, the FAA's technical training budget has been cut by 35 percent. People like Gabriel Kish are going to slip by.

Kish started out as a line mechanic in 1981, but by the middle of the decade he owned his own repair station in Florida. "The first couple years were great," he says, but as two major airlines, Pan Am and Eastern, went belly-up, so did much of his business. At that point he began doing what he calls "questionable overhauls," meaning he would charge a client the full fee for overhauling an aircraft component or system without having done much, if anything, at all. Strictly in terms of profit, it was a smart business decision. "On

Greenwich Air Services' Paul Streb looks over a Pratt & Whitney JT8D engine that will be test-run after its overhaul. Opposite: Inspector Tim Cone checks an engine vane for wear. Behind him approved parts are stacked to the ceiling in a central cage.

PHOTOGRAPHS COURTESY DOT OIG

(1) Counterfeiters' scams include printing fake mailing labels and plates engraved with serial numbers. The real Pratt & Whitney label is on the left. (2) The real data plates are on the upper left and lower right. (3) A rough finish on the inside of an engine spacer gives it away as a copy. The original has a smooth finish. (4) Counterfeit bolts have incorrect markings or often no marking at all. Parts pushers "cut" a bin of good bolts by mixing in substandard ones. (5) Broken starter gears were first welded and then painted and coated to hide the welds.

a single unit you can make $60,000," Kish says. "Sometimes as much as $100,000."

Kish eventually crossed paths with Classic Aviation's Rodney Kostoff, and his business became one of the FAA-licensed repair stations that built starters for Classic Aviation and fraudulently certified the work as FAA-approved. The last thing Kish worried about was the FAA.

"I didn't get into this to see how far I could bullshit the FAA," he says, "but it was so easy to do. They have no knowledge of what's going on." Inspections were cursory at best, he says, performed by inspectors who "never checked" whether he was certified to do the work he was doing, nor even looked to see if he had the required tools. "They were paperwork people," Kish says. "If the paperwork looked good, then everything else must be good."

The FAA closed Kish down, but only after being tipped off by law enforcement agencies. He is serving a 27-month prison sentence.

According to a 1994 internal report by the FAA System Surveillance and Analysis Division, the agency started "receiving a few allegations" of SUPs in 1988, but not until July 1992—after inspector general Mary Schiavo's crackdown—did the agency provide a standardized method for reporting SUPs. By 1994 the FAA's SUPs database and tracking system, according to the SSAD report, were still full of bugs, confusion, and mistakes.

Peter Friedman, a repair station owner and unapproved-parts consultant, says SUP reports represent only a fraction of the actual number of discoveries, which may be impossible to assess. "Who the hell is going to report that they almost installed a counterfeit part when they have to admit they didn't buy the part right in the first place?" he says. When a parts installer files a report, the agency essentially "dumps on the installer," according to Friedman. "Parts installers will not report [SUPs], the way women who get raped will often not report, because they don't want to become the focus of scrutiny. The FAA's data is worthless."

Harry Schaefer is convinced that airlines are deliberately under-reporting the problem. "It's bad publicity, so they'd rather just quietly return the parts for good ones or just take them as a tax loss and move on," he says. For example, during the early phases of the Classic Aviation case, Schaefer called an airline that he learned had bought some of Kostoff's fraudulently repaired starters: "I said I needed those starters held for evidence. They said okay, but next day they sent every one of them back to Classic and demanded a refund. There was nothing I could do because we hadn't gotten a subpoena yet." Of the 411 reports of suspicious parts received in 1994 alone, only 20 were filed by airlines. "And airlines are the biggest victims in this thing," Schaefer says, shaking his head.

Even with an artificially low number of reports, the OIG is kept busy. "There's no lack of cases," Schiavo said last summer. "If anything, we have to select very carefully. When I have precious few resources, you can bet I'm making [only] the biggest cases." Moreover, as Schaefer says, OIG investigators only go after those they are confident they can win, because, as with a bag of cocaine, it is extremely difficult to track a bogus part back to its origin. Investigations quickly become labor-intensive, time-

consuming navigations through a mass of criss-crossing paper trails that usually blur once inside the netherworld of brokers and distributors. Then there is the matter of preparing internal paperwork in order to secure various warrants—which, in turn, often result in seizures of small truckloads of more papers and records. "There's a lot of analytical work, a lot of research," says Schaefer. He spent nine years as a Metropolitan Miami-Dade County cop investigating racketeering and large-scale fraud, but Schaefer claims his current job is the reason he now wears reading glasses. "But without that paperwork," he says, "we can't prove a crime."

The OIG therefore decided that an ounce of prevention was worth a couple hundred pounds of paperwork. Schaefer began to hold seminars for industry people on how to identify suspicious parts. "The range of parts being counterfeited go from the smallest rivets to constant-speed drives," Schaefer tells his audiences. With charts and overhead projections he details the tricks of the counterfeit trade, tells the examiners what to look out for, and describes appropriate methods of verification. The seminars were only one of the inspector general's efforts to stem the tide of counterfeit parts.

Shortly after Mary Schiavo took office as the DOT inspector general in 1990, she initiated a series of audits evaluating the safety oversight programs of the FAA. The audits that addressed issues related to bogus parts uncovered, according to Schiavo, "serious, widespread, and unchecked problems." Not surprisingly, FAA management disagreed. The difference of opinion escalated into one of the most acrimonious bureaucratic battles the aviation industry has ever seen. The combatants slugged it out behind the scenes for three years until a May 1995 Senate hearing brought the fight into the open.

In this corner Inspector General Schiavo, a former prosecuting attorney who, finding widespread criminal activity, began to ring an alarm over the threat suspect parts pose to airline safety. Schiavo is best known for her outspokenness in the aftermath of the crash of ValuJet Flight 592. (The cause of the crash was a fire started by oxygen-generating cylinders in the airliner's cargo hold and had nothing to do with bogus parts.) On the same day she told reporters that she would not fly ValuJet, DOT Secretary Federico Peña proclaimed the airline safe to fly. The FAA subsequently grounded ValuJet.

And in this corner Anthony J. Broderick—then FAA associate administrator for regulation and certification, the agency's chief safety expert, who held a degree in physics. His position was that industry and FAA controls were sufficient to keep SUPs from being a significant safety threat, and he questioned Schiavo's competence on matters of airline safety. Broderick resigned in June, after the FAA came under fire for its poor oversight of ValuJet. Schiavo resigned two weeks later.


AP/MARK WILSON

Both Mary Schiavo and Harry Schaefer (about to take a seat to her left) told a Senate committee that the FAA had hampered investigations.

One of Schiavo's audits showed that suspect parts had penetrated even the FAA's own fleet of aircraft. In her testimony before the Senate subcommittee, she complained that in 1994 her small force of about 50 investigators had reported more suspected unapproved parts than 1,600 FAA inspectors. Schiavo accused FAA headquarters of doing everything it could to minimize the danger of SUPs. She said Broderick had interfered with her criminal cases, announced that he was the subject of an FBI investigation as a result, and recommended that he be removed. (The investigation was subsequently dropped.) She also told the committee that SUP reports from FAA inspectors were artificially low because FAA management had intimidated agency field personnel who might see the threat differently.

Schiavo was supported by a statement from the Professional Airways Systems Specialists, a union representing more than 10,000 FAA employees, including safety inspectors. The statement claimed that "there have been significant attempts by the FAA to delay the [SUP investigative] process, to mitigate the findings, to impeach [FAA] Safety Inspectors who conduct [SUP] investigations...or to cover up such investigations." Four FAA safety inspectors and a senior FAA official confirmed these allegations. Each insisted on remaining anonymous because FAA headquarters had made it clear that no one but approved spokespeople who reflected Broderick's viewpoint on the subject were to talk to the press.

The FAA, on the other hand, claimed that OIG investigators didn't understand what they were dealing with. William J. White, deputy director of the FAA's flight standards service, said after the hearing, "The OIG has only been in it a few years. We're the ones with the expertise."

When FAA administrator David Hinson addressed the committee, he explained that his agency did not consider SUPs a threat to safety be-

In the Greenwich "widebody area," Melia Rodriguez inspects the fan module of a Rolls-Royce RB-211.

cause the National Transportation Safety Board, which investigates aircraft accidents, had never attributed a crash to unapproved parts. Hinson also noted that although more than 1,000 SUPs had been reported between 1991 and 1995, only eight had caused the agency to issue an Airworthiness Directive (including the one issued to remove Classic Aviation starters). If the problem at large constituted a serious threat, the FAA would have imposed more Airworthiness Directives, compelling industry to search out and remove bad parts from their inventories.

Broderick made no formal statement to the committee, but afterward he summed up his position. "There are very, very few single failure points on an airplane that would cause an immediate catastrophic accident," he said last summer. The enormous amount of backup systems and redundancy in modern airliners provides a wide margin of safety against the failure of virtually any part, Broderick said. And most units, he added, are designed to contain any internal failures: "If a turbine blade breaks and goes flying off at the engine's highest RPM, it must be contained within the engine and then dribble out the tail pipe." Broderick made this statement a year before a Pratt & Whitney JT8D engine on an airliner blew apart on takeoff, killing two passengers. (Again, no counterfeit parts were involved. The failure was due to a flaw in a part that had been approved in accordance with regulations in place at the time.)

Some industry representatives sided with Schiavo; others, with Broderick. The Air Transport Association, for example, shares Schiavo's view that the FAA should regulate brokers and distributors. Regulating them would lighten the burden of inspection currently shouldered by the airlines. But the Aeronautical Repair Station Association, a lobby representing some 250 domestic repair stations, agrees with Broderick's contention that bogus parts don't automatically constitute a safety problem. Sarah MacLeod, the association's executive director, believes there is nothing wrong with the industry's own safety net, and she points for proof to the fact—confirmed by Schaefer and Schiavo—that most OIG cases on counterfeit parts develop out of tips and leads from inside the industry. The best example, she says, is the now-famous case involving counterfeit spacer seals discovered during an overhaul of Pratt & Whitney JT8D engines. The part is a narrow metal ring that fits between rotating engine blades and disks to separate one from the next. Duplication of product, packaging, and paperwork was good enough to slip past several airline quality assurance monitors and me-

chanics, and the spacer seals found their way onto aircraft. A United Airlines mechanic performing routine maintenance on an engine later discovered the fakes because of an odd discoloration they started to exhibit. United returned the part to Pratt & Whitney, and the manufacturer notified the FAA, which later issued an Airworthiness Directive warning airlines and repair stations to inspect the affected engines and replace the spacers.

"Now you tell me that this bloody system isn't working like she says it isn't," says MacLeod, who has often criticized Schiavo for reaching beyond her field of expertise when making pronouncements on the impact of SUPs. According to MacLeod, it's the inspector general's job "to ferret out fraud and abuse.... Counterfeiters are not the FAA's problem. They're *her* problem."

Schiavo never said they weren't. Between 1991 and the middle of this year, OIG investigations helped secure 133 convictions, $8.8 million in fines, and 96 years of prison sentences. Still, in many ways Schiavo's war on bogus parts resembled the nation's war on drugs. The cops were arresting individual criminals without eliminating the circumstances that enabled the crime to spread. Schiavo blamed the situation on the FAA for its hands-off attitude toward distributors and its failure to follow through on SUP reports with investigations and penalties. "There are several areas where the FAA has responsibility to oversee a lot of this and to regulate and inspect and they don't do it," Schiavo said. "And I think a lot of the counterfeiters know this."

One of the most controversial issues in the debate has been the FAA's ability to take action against parts distributors, entities that the agency does not regulate. However, Section 21.303 of the Federal Aviation Regulations states that "no person may produce a modification or replacement part for sale for installation on a type certified aircraft, engine or propeller, unless that part is produced pursuant to a Parts Manufacturer Approval," which only the FAA can issue. Many in the industry believe that this FAR gives the FAA some power over distributors and suppliers, including Edward J. Gluecker, the president of the Airline Suppliers Association, who said to the Senate oversight subcommittee, "Brokers, distributors, and dealers of aircraft parts are already subject to existing Federal Aviation Regulations.... FAR 21.303 applies to 'persons,' not exclusively to manufacturers."

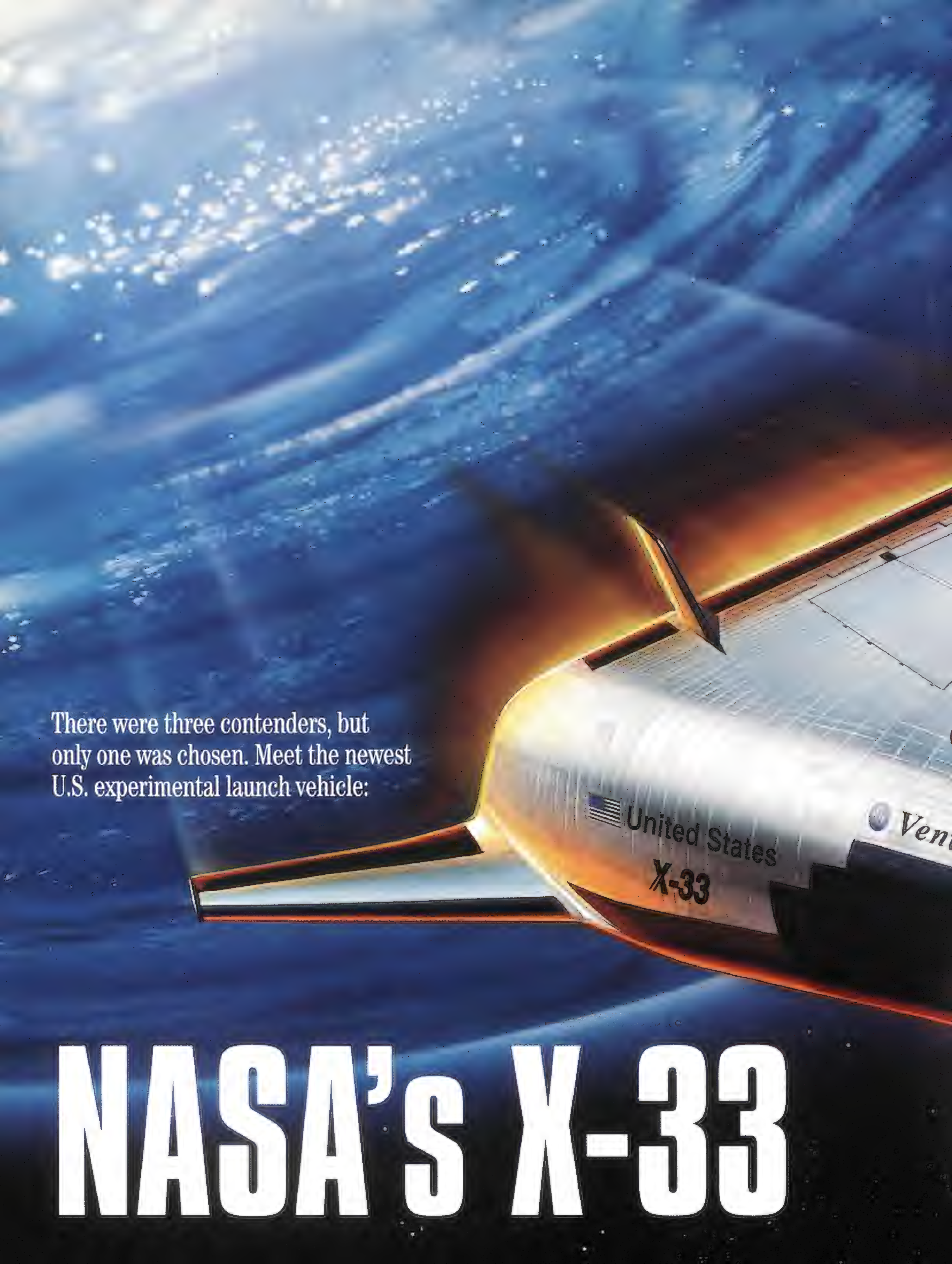
The senior FAA official who spoke on condition of anonymity interprets the regulation in a similar way. "It is the FAA's responsibility to make sure [bogus] parts aren't manufactured in the first place," he says. "But the agency has taken no action to put any of these people out of business."

The FAA does not have the search-and-seizure power of law enforcement agencies, so it would be difficult—though not impossible—for the agency to take action against a broker, and as Schiavo pointed out, the brokers know the agency is reluctant to do so. The thorny issue of FAR 21.303 is unresolved. On other issues, however, the FAA tacitly conceded ground. The agency appointed a task force to plan how it could "more aggressively address SUPs." In a report issued last fall, the task force announced its recommendations. SUP reports, now voluntary, may become mandatory for all agency-approved repair stations, airlines, and mechanics. The agency may also require the mutilation of spent parts. The report did not recommend that new regulations be written for suppliers and dealers or that they come under FAA oversight, as Schiavo had urged. Instead, it encouraged them to create a voluntary accreditation program. The task force explained this decision by noting, "Even without directly regulating them, the FAA does have some avenues that it can pursue if it finds an 'unapproved parts' problem in connection with distributors or brokers."

The SUP task force also recommended that FAA inspectors receive more training in identifying SUPs and working with law enforcement agencies in investigating them. So in Harry Schaefer's seminars on how to recognize counterfeit parts, he now includes FAA inspectors. Today, however, he is speaking to about two dozen extremely attentive mechanics, receiving clerks, QA inspectors, purchasing agents, and managers from Greenwich Air Services. The overhead projector is on, and Schaefer is showing slides of counterfeit bolts. Sellers of substandard bolts will often spread maybe a hundred good ones atop a barrel full of bad ones. "So you need to dig under the top for a random sample and check if there are head-markings on the bolts," says Schaefer. "Counterfeits usually don't have head-markings."

Outside, jets roar down the runways of Miami International Airport; inside, Schaefer lays out a table full of bogus parts—some, like a set of engine spacers, placed beside the genuine article. Few members of the class can tell the difference.

The FAA estimates that 26 million parts are changed on airliners every year. Maintenance facilities must verify them one part at a time.



There were three contenders, but only one was chosen. Meet the newest U.S. experimental launch vehicle:

NASA's X-33

by Bruce D. Berkowitz

When NASA chose the Lockheed Martin Corporation last July to develop the experimental X-33 launch vehicle, it in effect created a $941 million experiment to settle a decades-long debate: Does the technology exist to build a self-contained vehicle capable of traveling to orbit and returning to Earth, deploying payloads so economically that it puts expendable boosters out of business?

Experts have argued for years that the way to lower launch costs is to develop a truly reusable launch vehicle (RLV). Lockheed's X-33 design was one of three competing proposals to begin to do just that. In each, the ultimate goal was an RLV more reliable and less costly to operate than the vehicle it is intended to replace, the space shuttle. Each proposal addressed both a full-scale RLV and a smaller-scale X-33 that would test the technology needed to achieve it.

The competition also showed how three teams, when presented with the same problem, can arrive at three different solutions. To understand why—and why NASA chose Lockheed—it helps to understand why building a reusable vehicle is so challenging in the first place.

PAINTING BY PAUL DiMARE

The RLV Challenge

Space enthusiasts often say the ideal launch vehicle would operate like an airliner. It would simply take off, drop its payload into orbit, and return to Earth for another mission. Unfortunately, getting into space and returning to Earth are completely different technical problems. To make matters worse, solutions for getting into space usually conflict with solutions for getting back.

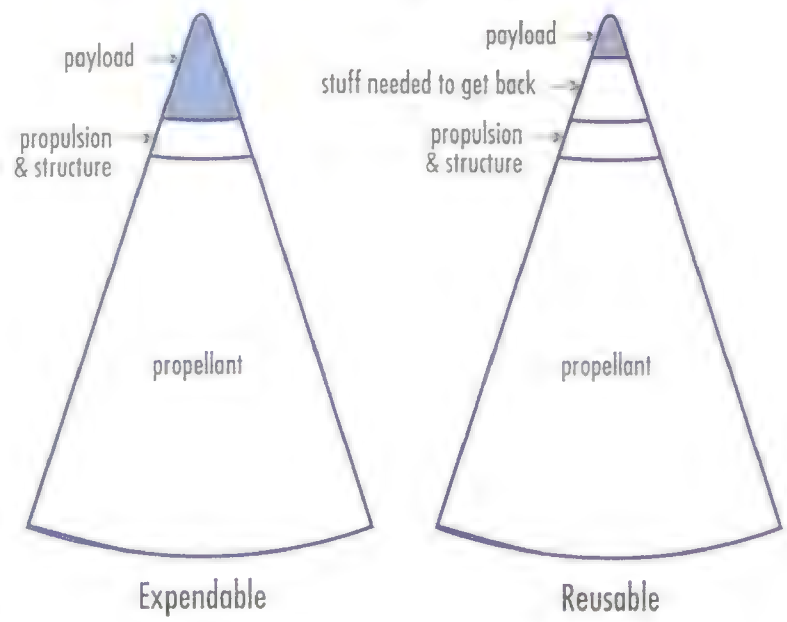
Getting into orbit is mainly a matter of velocity. To stay in orbit a vehicle must reach a velocity of nearly 18,000 mph, about Mach 25. This is why X-15 pilots could fly high enough in the 1960s to qualify as astronauts but could never reach orbit: The X-15 could fly only to Mach 6. To achieve orbit, the vehicle would have needed less mass or more energy.

That's the challenge of getting into space: designing a spacecraft that can generate enough power and carry enough fuel to push its own weight—and, ideally, that of some payload—to orbital velocity. One measure of success is a ratio called "mass fraction": the weight of the propellant the vehicle requires to achieve a specified orbit divided by the gross liftoff weight (GLOW) of the fully loaded vehicle. The lower the mass fraction, the more efficient the vehicle. An efficient launch vehicle like Lockheed Martin's Titan IV, which frequently launches shuttle-class payloads for the Air Force, has a mass fraction of about 0.87. That is, the Titan weighs about 4.1 million pounds on the pad; of this, 3.6 million pounds is propellant and the remaining 500,000 pounds is airframe, engines, avionics, and payload.

Because they are expendable, launch vehicles like the Titan can drop excess weight as they climb, reducing the amount of energy required to reach orbit. With the Titan IV, for example, a first stage, two large solid boosters, and a payload fairing—about 240 tons of hardware—go sailing into the ocean rather than into space.

Indeed, one strategy to reduce the cost of getting into space is simply to reduce the cost of the stuff you discard and streamline ground operations. The Air Force is using this approach with its planned Evolved Expendable Launch Vehicle. Currently it costs about $6,000 to put a pound of payload into low Earth orbit using a Titan. The Air Force hopes the EELV will lower the cost by 25 to 50 percent.

WHY AN RLV IS HARD TO DESIGN



The other way to reduce launch costs is to recycle the hardware, the approach that is the essence of the reusable launch vehicle. But that presents even bigger challenges. A reusable vehicle has to haul into orbit all of the stuff it needs to get back: retro-firing motors, extra-strength airframe, thermal protection, something to slow the vehicle's descent for landing, and so on. All that comes at the expense of payload.

There are other complications. For example, if an RLV consists of more than one stage, the costs of recovery and refurbishment double or triple. This is one reason why the space shuttle is expensive to operate and why most proposed RLVs—including the three that were in the competition—have just one stage, even though that configuration cuts significantly into performance.

Adopting a single-stage design means that you need a motor that works efficiently at both low and high altitudes. This is a problem. Because atmospheric pressure is reduced at higher altitudes, rocket motor nozzles need to be large in order to maintain a high level of thrust. However, a nozzle large enough to work optimally at high altitude would resonate dangerously in the greater atmospheric pressure at lower altitudes. There are no perfect solutions. One approach is to use a compromise design. This sacrifices performance. Or you can use an adjustable nozzle that expands in higher altitudes—but this increases weight and adds another mechanism that can fail.

With so many challenges, it's little wonder NASA has divided its quest for a reusable launch vehicle into stages. Phase 1, announced in March 1995, gave three companies money to develop detailed plans for building and operating a reusable vehicle: Rockwell International, McDonnell Douglas Aerospace, and Lockheed Martin (or, as they are known in the industry, Rockwell, MacDac, and LockMart). It also funded new technology programs to develop structures and tanks from lithium-aluminum and composites. Phase 2, which is presently under way, funds the construction and testing of the X-33. There was money for only one X-33 vehicle, hence the competition. Assuming that Phase 2 is completed successfully and funding is available, Phase 3 will entail the building of three operational RLVs. The vehicles are to cost about $5 billion; NASA, which is positioning to buy rides rather than operate launchers, expects industry to foot most of the bill.

All three proposed X-33s shared some characteristics: All were to be launched vertically and all used some of the technologies demonstrated in Phase 1 to improve mass fraction and reliability. The Rockwell and MacDac entries even used the same engine. But there were at least as many differences as similarities.

Shuttle Redux

Rockwell built the space shuttle, so it's little wonder that its entry in the competition for the shuttle's successor fell in the category of "new and improved" rather than "radically different." Rockwell wove terms like "heritage" and "validated databases" throughout its proposal. "That was our fundamental strategy: to take a low-risk approach," says Thad Sandford, director of Rockwell's X-33 program. The idea was to

make the most of NASA's shuttle experience and add the technology necessary for full reusability and lower-cost operations.

Rockwell's proposed RLV resembles the shuttle minus the expendable external tank and two solid rocket boosters. The engines, RS-2100s designed by Rocketdyne, were derived from the space shuttle main engine (SSME) but produce 23 percent more thrust. By using six of these rather than the shuttle's three, Rockwell was able to eliminate the solid boosters—a high-maintenance, high-cost item in shuttle operations. Rockwell's X-33, a 48-percent scale version of the RLV, would have used a single SSME.

(Rocketdyne, incidentally, is a Rockwell subsidiary. Since all the X-33 and RLV proposals used Rocketdyne engines, Rockwell was positioned to leave the table with something, even if NASA rejected its concept.)

The Rockwell RLV looks so much like the shuttle that one could easily underestimate the innovations it embodied. "From the outside they look fairly similar," acknowledges Charles Scottoline, who led Rockwell's proposal team, "but technological advancements have made them vastly different machines."

The shuttle was developed in the 1970s, so it was designed on drafting boards. Current computer design tools allowed Rockwell to trim weight in the airframe and still build in adequate safety margins. Also, the shuttle is made mainly of 1970s-vintage materials: Rockwell planned to use composites for major load-bearing structures such as the motor mounts and incorporate lighter-weight alloys elsewhere. It also planned to reduce the vehicle's size (and thus total mass) by using high-density propellants it had developed.

Rockwell's strategy reflects the basic principle that led NASA to believe an RLV was feasible now. Even using a conservative design, current technology makes it possible to reach orbit in a single stage with at least *some* payload. Thus, getting a payload of a given size into space is really just a matter of increasing the size of the planned vehicle until it is big enough to carry it.

For example, Rockwell's RLV was to weigh 2.2 million pounds and be capable of delivering a payload weighing 25,000 pounds—about one percent of GLOW—to the orbit of NASA's planned space station. If current technology were a little less efficient—say, if the RLV could lift only .75 percent of GLOW to that orbit—Rockwell could solve the problem simply by designing a 3.3 million-pound vehicle. By comparison, using 1970s technology, the 4 million-pound shuttle can also lift about one percent of GLOW to the space station orbit, but it needs to discard two boosters and an external tank in the process.

Yet a key part of Rockwell's proposal concerned not the vehicle itself but its operation. In essence, the company's proposal argued: *We've been working with the shuttle for more than a decade, we know what makes it expensive, and our technology will make it cost less.* So while its RS-2100 engine was based on the shuttle's main engine, the design used components that required less maintenance. The vehicle would have used the electronic diagnostic systems common to modern aircraft. Rockwell also planned a containerized payload system (it included Federal Express on its team to provide advice on streamlining ground operations) and technologies that would permit faster fueling, less maintenance, and fewer people on the ground.

Ultimately, however, pedigree and incremental improvements were not enough. But Rockwell can at least take comfort in knowing that NASA plans to keep flying the shuttle until 2012.

Son of Star Wars

McDonnell Douglas' X-33 entry was the favorite of space aficionados who were longtime critics of NASA. They had argued that a reusable single-stage-to-orbit (SSTO) vehicle had been feasible for years, if only the agency would break out of its bureaucratic tunnel vision. Read the literature and the World Wide Web pages promoting SSTO and you get a sense of zealots at work.

The MacDac RLV concept traced its lineage to studies that the Department of Defense's Strategic Defense Initiative Office sponsored in the 1980s. SDIO needed a way to get many satellites into space cheaply: The assumption was that neither the shuttle nor traditional expendables were up to the job.

The McDonnell Douglas vehicle resembles a traffic cone and is the simplest possible combination of structure, propellant, and motors. But the most distinctive feature of the MacDac en-

try is how it would land. Unlike the Rockwell and LockMart vehicles, which would glide to a landing on a conventional airstrip, MacDac's would drop through the atmosphere, rotate right side up when it reached an altitude where its flaps became effective, then restart its engines to gently settle to the ground.

Vertical landing supporters insist that this wingless design is not just feasible but optimal. By leaving off the wings you reduce weight. This not only increases the amount of payload the vehicle can carry, it also simplifies reentry. Returning from space, the vehicle would resemble a tin can, blunt-shaped and with a minimum of mass for its volume. This would allow it to drop through the atmosphere more slowly, reducing atmospheric heating.

As for those who have qualms about plummeting multibillion-dollar vehicles, MacDac argued that a vehicle descending vertically under power is at least as safe as a vehicle gliding down unpowered—indeed safer, because it can avoid obstacles on the ground. It can also land on a greater number of sites than a craft requiring a runway. Landing did prove to be a problem, however. A prototype was destroyed last July when its landing gear failed to deploy correctly in a test flight.

McDonnell Douglas had begun demonstrating its concept with the sponsorship of SDIO's successor, the Ballistic Missile Defense Organization. MacDac first flew an earlier prototype called the DC-X in 1993 at White Sands Missile Range in New Mexico (see "Single Stage to...Where?," Feb./Mar. 1994). The program ran out of money (BMDO was never a favorite of the Clinton administration), and in 1995 the vehicle was transferred to NASA, which incorporated it into its overall RLV project as a testbed.

MacDac's X-33 design used off-the-shelf engines: one Rocketdyne SSME supplemented by six Pratt & Whitney RL-10s (the same engine used in the Centaur upper stage of the Atlas and other launchers). The full-scale RLV would have used the new RS-2100.

MacDac's plan was, to use industry jargon, "build a little, test a little," moving up in size and power from the DC-X to the X-33 and then on to the RLV.

Each vehicle was to be developed in steps too, progressing from static tests on the ground to hover tests and then gradually to higher and faster flights. MacDac likened this approach to how it tests its new airliners. Flights to test the latest version of the prototype, the DC-XA, were funded through the end of this year, but, as this magazine went to press, the July crash had left the future of the cooperative NASA-McDonnell Douglas effort looking dim.

From the Folks Who Brought You the Blackbird

Lockheed's Skunk Works has long had a reputation for building hardware slightly beyond the leading edge of technology. Examples include the U-2 (after 40 years, still the highest-flying single-engine aircraft), the SR-71 (after 30 years, still the fastest jet aircraft on record), and the F-117A (after 10 years, still the only known stealth fighter).

LockMart's RLV design follows this tradition. Called VentureStar, the proposed spacecraft has two features that set it off from the others: an aerospike engine and a lifting body design.

The aerospike engine solves the problem of designing a single rocket motor that works efficiently in both the atmosphere and space. Unlike a conventional engine, in which propellants are burned inside a combustion chamber and the exhaust exits via a nozzle, with the aerospike engine, propellants burn on the outside around a central spike. Atmospheric pressure and airflow around the engine contain the combustion process, taking the place of both the combustion chamber and nozzle of a conventional engine. Without a fixed-dimension nozzle, the engine is able to adjust to different altitudes as the vehicle ascends.

In effect, the engine is an inside-out version of the J-2 engine Rocketdyne built for the second and third stages of the Saturn V Apollo booster. It uses the J-2's turbopump machinery and has the propellant injectors in two rows on either side of the spike. Rocketdyne will develop a larger version of the engine for the RLV.

Bob Baumgartner, Lockheed Martin's RLV program manager, explains, "It's an integrated package and has a lot of synergism. By integrating the aerospike engine with the airframe, we are able to get thrust vectoring without gimballing." What he means is that with a conventional motor, the nozzle must swivel to guide the vehicle. The aerospike engine instead increases or decreases propellant flow to one side of the spike. "This design transfers loads directly into the airframe and eliminates flex lines for the propellants," Baumgartner says.

To return to Earth, LockMart designed VentureStar as a lifting body, or wingless vehicle. The company's ob-

jective was to design a vehicle that would glide to a landing (avoiding the risks of the MacDac approach) while also avoiding the weight of wings (a drawback of the Rockwell design). Wings are also hard to protect from the heat and aerodynamic stress of reentry, so a lifting body design has that advantage as well.

Fifteen flights are scheduled for LockMart's X-33, all in 1999. Although the vehicle will be limited to a maximum velocity of Mach 15 and will never reach orbit, Baumgartner notes that "95 percent of the mass fraction improvements we need for the RLV will be validated in the X-33." In other words, if Lockheed's X-33 works as planned, so will its RLV.

But Will It Work?

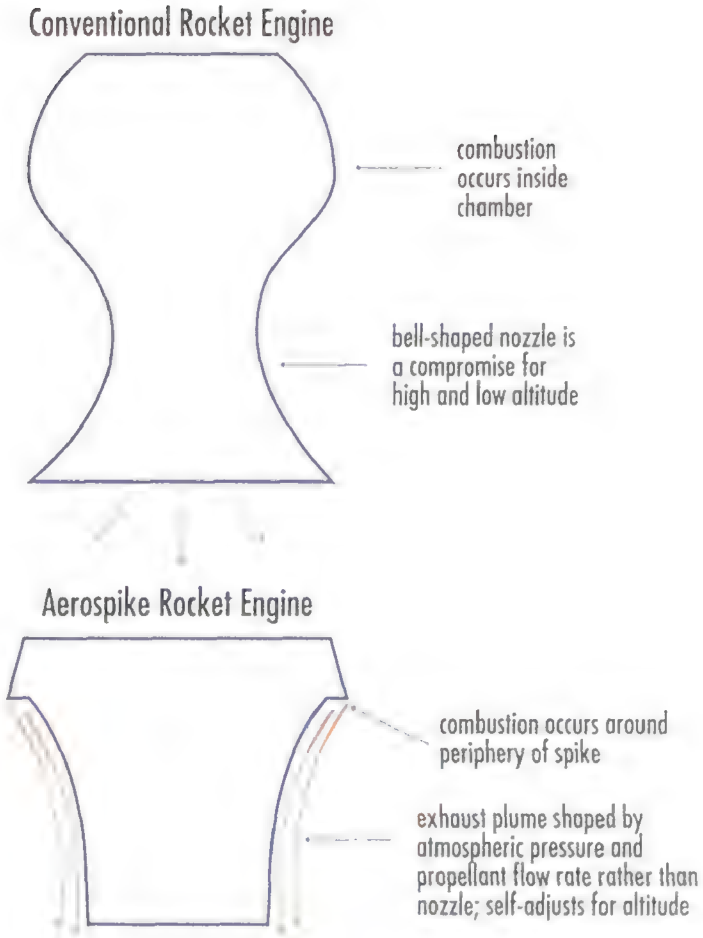
Developing an RLV is more a matter of struggling through a technology thicket than breaking a conceptual barrier. You are never free of the basic problem of power and mass; you just develop better technology for dealing with it, squeezing out more efficiency from motors, materials, and propellants.

All three proposed RLV designs were ambitious. In effect, they would provide mass fraction equal to that of expendable boosters, but without separate stages and with enough extra lift capacity to accommodate the additional strength and systems necessary for reuse. Those gains are a direct reflection of the technology that has been developed since the shuttle was designed.

Of course, technological progress is not the only issue. Add up the costs to develop, build, operate, and maintain a reusable vehicle, then divide by the number of flights it can make; the cost must be less than that of a cheap, reasonably reliable throwaway booster.

"We said, 'Tell us what all of the business and technical risks are and how you are going to meet them,' " says Steve Cook, X-33 deputy program manager at NASA's Marshall Space Flight Center in Alabama. "In the end, Lockheed had the best overall plan for getting you there."

NASA believed Lockheed's X-33 was closer to being a miniature version of



its RLV and would flight-test more of the technologies to be used in the full-sized launch vehicle. Rockwell and MacDac would have left some components and systems to be tested during their RLV programs. Thus, even though Lockheed's X-33 will use a new engine, NASA felt that by the time the RLV would get the go/no go, Lockheed would be closer to an operational vehicle.

Yet the most important thing about the X-33 may be what it says about NASA today. "This is a program where we are not afraid of risks," says Gary Payton, director of RLV programs at NASA headquarters. "The objective is to address risks *before* production."

Even so, in a no-wager pool on the Internet, Rockwell was the betting favorite. It was also the front-runner among the media and think tank pundits (and, for that matter, some of the staff of a certain aerospace magazine as well as a certain writer). The common wisdom was that NASA would lean toward a conservative, evolutionary design offered by its largest contractor. The fallback favorite was McDonnell Douglas, which already had a prototype flying and which had built the Mercury and Gemini capsules. "Guess you haven't been listening to Gary Payton and Dan Goldin for the past two years," scoffs Payton.

In selecting the Lockheed Martin proposal, NASA made clear that it is serious about doing things differently. Even though the agency insists its decision was based on Lockheed's overall development strategy and business plan, the fact remains that it chose the most radical, ambitious design. It selected the one contractor that had never developed a space vehicle for the agency before. Until the X-33 flies in 1999 and VentureStar begins operations sometime in the next century, we won't know for sure if NASA's won its bet. But by any measure, it's a gutsy decision.

COMMENTARY:

Close Encounters of the Unlikely Kind

On February 17, 1600, an Italian monk, Giordano Bruno, having been excommunicated by the Inquisition for refusing to renounce his heretical opinions about worlds beyond Earth, was burned at the stake in the Campo dei Fiori in Rome. In 1584, Bruno had published *On the Infinite Universe and Worlds*, stating that "it is impossible that a rational being…can imagine that these innumerable worlds, manifest as like to our own or yet more magnificent, should be destitute of similar and even superior inhabitants." Through seven years of close confinement Bruno refused to modify his belief that the universe contains infinite worlds, all as worthy of God's mercy as our own Earth may be. Finally despairing of changing his mind, the Catholic Church judged Bruno fit for execution.

Four centuries later, most of us easily accept the notion that our Milky Way galaxy contains inhabited planets, a concept supported by the recent discoveries of more than half a dozen planets orbiting sun-like stars. But despite an apparent improvement in understanding the cosmos, the public remains as fastened as ever upon an intuitively attractive—though utterly incorrect—belief: that our Earth is the natural focal point of extraterrestrial creatures. From H.G. Wells' *War of the Worlds*, written nearly a century ago, through the cold war-induced hostility evident in films such as *The Thing* and the era of good feelings about extraterrestrials embodied in *Close Encounters of the Third Kind* and *E.T.*, we've seen that when extraterrestrial beings ask themselves, "Where shall we go today?" they invariably think of our planet. The blockbuster movie *Independence Day* joins this tradition, depicting an alien civilization bent on the destruction of Earth and apparently quite capable of achieving it until human bravery, boldness, and ingenuity prove more than its match.

What sort of misanthropic, cranky gadfly criticizes successful books and movies, not for their shortcomings as entertainment but for their mindset and world view? I gladly assume this role in order to emphasize that when we conceive ourselves as the central point in the cosmos, our minds fall into a pit of darkness. By catering to our instinctive assumptions, rather than dealing with the cosmic facts of life, *Independence Day* and its long series of predecessors encourage our foolishness in judging our chances for encounters with extraterrestrial civilizations. If you give me a few minutes, I'll brief you on the news from the real astronomical world, and attempt to prove why it deserves your attention more than all the science fiction movies yet made. (Then, having lost one more battle, I shall settle down and re-read some of my favorite books.)

Ever since Bruno's era, astronomers have recognized that our sun is one of a multitude of stars. If nothing extraordinary distinguishes our own star, it should follow that many or most of the others have planets of their own—and potential sites for extraterrestrial life. Until late last year, however, no planets had ever been detected around any star similar to the sun. No one expected to *see* such planets, which would nestle close to their stars and shine only weakly by reflected starlight, but various indirect methods to find planets had been employed, and none had succeeded. All that changed last October, when two Swiss astronomers, Michel Mayor and Didier Queloz, announced their discovery of a planet around the star 51 Pegasi. Three months later, U.S. astronomers Geoff Marcy and Paul Butler, friendly rivals of Mayor and Queloz, presented their first two planets, orbiting the stars 70 Virginis and 47 Ursae Majoris, to the astronomical community.

Both teams had made their discoveries by observing stars and finding repetitive variations in their motions toward or away from us that implied the existence of planets. Displaying what scientists call the Doppler effect, these motions change the precise colors of starlight depending on the star's velocity along our line of sight. Increasingly accurate measurements of Doppler effects on a star's light now al-

ALAN E. COBER

In our search for other life in the cosmos, Donald Goldsmith argues that we first must reassess our position here.

low astronomers to detect planets that influence their stars' velocities by only a few meters per second. Because these changes recur in a cyclical manner, the astronomers observing them conclude that the star is responding to the gravitational pull of a planet by moving in a small orbit around the center of mass of the system it forms with the planet. The planet moves in a much larger orbit—though with the same orbital period and same shape as the star's orbit—because the planet has far less mass than the star and therefore responds far more readily to the gravitational force upon it. The change in velocity and the orbital period reveal both the mass of the planet that pulls on the star (planets with larger masses produce greater changes in a star's velocity) and the distance between the planet and its star (smaller distances also produce greater velocity changes). Finally, the way in which the star's velocity changes with time reveals whether the orbit is circular or elongated. All together, that's not a bad set of deductions, considering that these stars are several dozen light-years away—nearly a million times the distance Jupiter is from Earth.

By now astronomers have found at least half a dozen planet-like objects orbiting sun-like stars in our corner of the Milky Way. Some may turn out to be brown dwarfs, objects with many times the mass of Jupiter, the most massive of our solar system's planets. Like stars, brown dwarfs heat themselves through gravitationally induced contraction of their interiors; unlike stars, they never succeed in raising their central temperatures to the point where thermonuclear fusion begins.

To astronomers, though, the crucial distinction in stellar companions lies not between brown dwarfs and stars but between brown dwarfs and planets. Brown dwarfs are believed to form the same way stars do, from the gravitational contraction of a single mass of gas and dust. Planets, in contrast, are thought to form from small agglomerations of dust, left over as a star forms at the center of a rotating "protoplanetary disk" of matter. Some of these dust particles eventually run into one another and stick together, producing mile-wide "planetesimals" that eventually collide with one another to make planets. In this model, one would expect to see planets born in nearly circular orbits, the result of having been part of the rotating disk of material. On the other hand, stars and brown dwarfs, if they form as part of a double-, triple-, or quadruple-object system, can and do have highly elongated orbits.

News from the real astronomical world deserves your attention more than all the science fiction movies yet made.

Of the first six objects to be discovered by measuring the Doppler effect, two may be brown dwarfs. But the remaining four seem certain to be planets. With masses ranging from about half Jupiter's to four to six times that, these four move in nearly circular orbits. But what amazed astronomers, and stood theories of planet formation on their heads, was that all four orbit their stars at distances less than five percent of the distance between the sun and Earth! These distances are less than 13 percent of the distance from the sun to its closest planet, Mercury.

Astronomers currently have no way to explain how such massive planets could form so close to their parent stars. Because a star's heat will evaporate the lightest, most abundant elements, all formation models conclude that only at distances at least three to four times greater from a star than Earth is from the sun can an object accumulate a mass similar to Jupiter's. As a result, all attempts to explain how these Jupiter-like planets come to orbit so close to their stars require that these planets form a hundred times farther away and then somehow move inward. How would this occur? Theories favor a gravitational interaction between the remnants of the protoplanetary disk and the newborn planets, with the disk tugging the planets inward as it evaporates.

Even if this theory proves inadequate, however, there's a crucial point here regarding our desires to meet other creatures: Any process that moves Jupiter-like planets inward will almost surely consume Earth-like planets that may have formed in Earth-like orbit. These might-have-been-Earths would be caught by the larger planet's gravity and would become part of the giant planet as it migrated inward toward its

The author's book, *Worlds Unnumbered: The Search for Extrasolar Planets*, will be published by University Science Books in January.

star. Thus the recent planet discoveries, though encouraging to those who search for other worlds, suggest that Earth-like planets may be far rarer than we once thought. If so, then the same may apply to the existence of life even vaguely similar to our own.

To be sure, not all of the newly discovered objects move in the close-in orbits described above. The one revolving around 70 Virginis has an orbit 43 percent of the size of Earth's, which might allow water to exist as a liquid, a condition that some regard as necessary for life. However, this object, with more than six times Jupiter's mass, almost surely has no solid surface where liquid water could form. It may be a brown dwarf, generating so much heat that both liquid water and life similar to our own could not exist there. It's also important to note that the Doppler effect method favors finding close-in objects, which have greater influence on their stars' velocities: Hosts of farther-out planets still await detection. Furthermore, our theories about how life originates and evolves are tentative and will remain so until we find in the cosmos at least one other form of life with which we can compare our own.

But the chief lesson from these newly discovered planets seems to be that if we want to find Earth-like planets, it will not suffice to find Jupiter-like planets and deduce from them that smaller planets exist in the same system. Instead, we must plan somehow to discover those other Earths directly, a far more difficult task—one that may require the construction of a specialized "interferometer" system. This interferometer would consist of several telescopes, separated by distances ranging up to 100 meters, that could observe an object and compare images of it simultaneously. Provided that variations in the distances between the telescopes be accounted for to an accuracy of several picometers (a picometer is a trillionth of a meter), this system could produce images equal to those of a single telescope with a mirror nearly as wide as a football field, capable of revealing Earth-like planets orbiting sun-like stars.

Recent planet discoveries suggest that Earth-like planets may be far rarer than we once thought.

NASA has recently developed a 25-year plan to send such a system out to Jupiter's distance from the sun to detect extrasolar Earths. Should this effort receive funding, many of you may live to witness the first discoveries of our planetary twins: planets similar enough to Earth that they could harbor life.

In these matters I am hardly neutral. Like most astronomers interested in the search for extraterrestrial intelligence, I know of no possible discovery with greater potential impact on our civilization. Our searches aimed at "eavesdropping" on another civilization's radio signals have barely begun, and they require searching billions of separate frequencies in millions of directions. Nevertheless, they could succeed in a year, or a decade, at a cost comparable to that of a low-budget film and immensely less than sending one of the spaceships so beloved by Hollywood producers on an interstellar journey at speeds far less than the speed of light. As Carl Sagan puts it, even negative results from these searches will "calibrate our place in the cosmos" by telling us how rare our sort of existence may be.

Those who have no use for such searches can command my respect if they are willing to debate the reasons why even a modest expenditure seems to be a waste of time and money. What leaves me feeling hopeless, though, is an opposition arising from the continuing human belief in our centrality in the cosmos—that any aliens out there will inevitably be drawn to us. I can appreciate that extraterrestrials provide convenient cinematic villains, unaffiliated with any group that might feel stigmatized. But so long as the attitudes exemplified by *Independence Day* and its like remain fixed deep within our minds, what chance exists for a fuller understanding of the cosmos?

To cheer myself up, I think of Giordano Bruno, who failed to convince either the public or those in authority that our planet is just one among a host of others. Join me! Look deep inside, examine your belief in the centrality of human existence, and tell yourself that you will strive to overcome this prejudice and recognize that the universe contains an enormous number of planetary systems, separated by truly immense distances. Only when a sufficiently large portion of the human population does so can we put aside our cheerful but childish enjoyment of the extraterrestrials who visit us in films, and regard seriously the process of discovering what types of life (if any) actually exist on the planets that we now know to sprinkle the Milky Way.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Bless Our Happy Missile Silo

For Sale: Fixer-upper. Spac., 3+ bdrms. Fifties charm. Built to last. Big bsmnt.

by Nate Ferguson

Photographs by Jay Koelzer

Dianna Ricke-Peden walks through the 120-foot tunnel that connects her family's underground home with the outside world. The Pedens' living quarters were once the control center of an Atlas missile base—one of nine installed around Forbes Air Force Base in Kansas in the early 1960s.

The Peden family has given up seeing sunsets. Ed Peden, an ultralight aircraft manufacturer, and Dianna Ricke-Peden, a speech therapist, live on Atlas E missile base no. 6, just southwest of Topeka, Kansas, and their home lies beneath three feet of earth. The section they use as a garage once housed a thermonuclear missile capable of flying 6,000 miles away and producing a four-megaton explosion.

Today, there are at least 15 decommissioned Atlas missile sites for sale, ready for transformation. Mark Hannifin of Midland, Texas, bought one that was flooded with 130 feet of water: he uses it for giving scuba diving lessons. And about an hour from the Pedens' home, a missile base north of the town of Holton has been converted into a public high school. The entrance tunnel, which once connected the missile's launch area with its control center, has been painted red, white, and blue by the Jackson Heights High School student council.

Atlas missiles were America's first intercontinental ballistic weapons; 100 were installed in permanent sites around the country during the late 1950s and early '60s, mostly in the Midwest. The Pedens' is one of 21 that went up in Kansas, which was happy to get the accompanying infusion of money. A 1958 story in the *Topeka Capital* was headlined: "Missile Base Is Viewed With Joy"; another, in a 1961 edition of the *Kansas City Star*, began: "What is happening in Kansas is almost incredible, and so awesome it shakes you right down to your boots. In a matter of a few months, Kansas will be the nation's No. 1 springboard for long-range missiles."

The Atlases were decommissioned only four years later, when they were replaced by Titan IIs and Minutemen. In the years following, the Atlas sites were dispersed among local governments, companies, and individuals by the federal government's General Services Administration. Realty specialist John Robinson of the GSA's Ft. Worth, Texas office says he gets hundreds of calls every year from prospective missile base purchasers (though the GSA no longer has any Atlas sites for sale, it does have sites once occupied by second-generation missiles). "Most want them for secure storage, and paranoid people want bomb shelters," he says. "Others want to grow mushrooms."

At least one other Atlas site has been transformed into a home, but that silo dweller guards his privacy assiduously. The Pedens, on the other hand, are happy to share their story.

Back in the early 1980s, Ed Peden, then a teacher of history and psychology in the Topeka public school system, began to hear talk of Atlas sites in the area. He got his first look at missile

base no. 6 in 1982; when he went to inspect it, the underground portions were flooded, and he had to conduct his tour with a canoe and a flashlight. But he saw the possibilities, so he paid a scrap dealer $40,000 for the property. It was a good deal: He got a 33-acre site with a landing strip, plus 15,000 square feet of available underground space. The ceilings were so high he was able to put in an upper level that added 3,000

The Atlas housed at the Pedens' site was an E version, which was stored horizontally; it was raised up before a launch or a demonstration of readiness (right).

To dramatize the base's image as a defense post, Ed Peden transformed some old gas station fuel tanks into two castle-like turrets for the site. Below, the Pedens pose atop the one that sits over their living quarters; the other turret, situated over the base's fire tunnel, is visible in the distance.

DAVID MATHIAS

square feet. Ed had long been interested in underground housing because, according to its advocates, it requires less energy to heat and cool. And he was able to use part of the launch area for assembling the ultralight aircraft he sells.

Today, two years after they finally moved in, the home portion looks fairly conventional, though a few structural inconveniences remain. It takes the Pedens several minutes to answer the doorbell, for example, as they have to walk the length of a 120-foot tunnel. The tunnel makes an eerie foyer. When the double steel doors at the end are slammed, they send dungeon-like echoes off the walls, as if you are entering another world or a really big basement. At the other end, a wooden door opens onto the former control center, now the Pedens' home. At 2,800 square feet, it's about the size of a typical suburban rambler. The inside seems unremarkable, except that the rooms have 15-foot ceilings and at the entrance to the living quarters is an old panel with switches for initiating a launch.

Though the living space is comfortable enough, once in a while the Pedens' two daughters, Ashley and Heather, mutiny. "Dad, why do we have to live in a hole in the ground?" they ask. The Pedens do plan to build living space above ground eventually.

Last year, Peden teamed up with former student Tim Schwartz to form the Twentieth Century Castle Company, essentially a real estate agency for old Atlas bases. As of August, they had sold six, gotten a sales contract on a seventh, and obtained listings for 15 more.

Recently, Ed Peden drove a visitor to a site that he'd sold to a spring manufacturer. Located in the Kansas town of Wamego, the site, says Peden, was the nation's best preserved "E"-type (of the three Atlas variants made, the "D" and "E" were stored horizontally, to be raised by crane in the event of a launch, and the "F" was stored vertically).

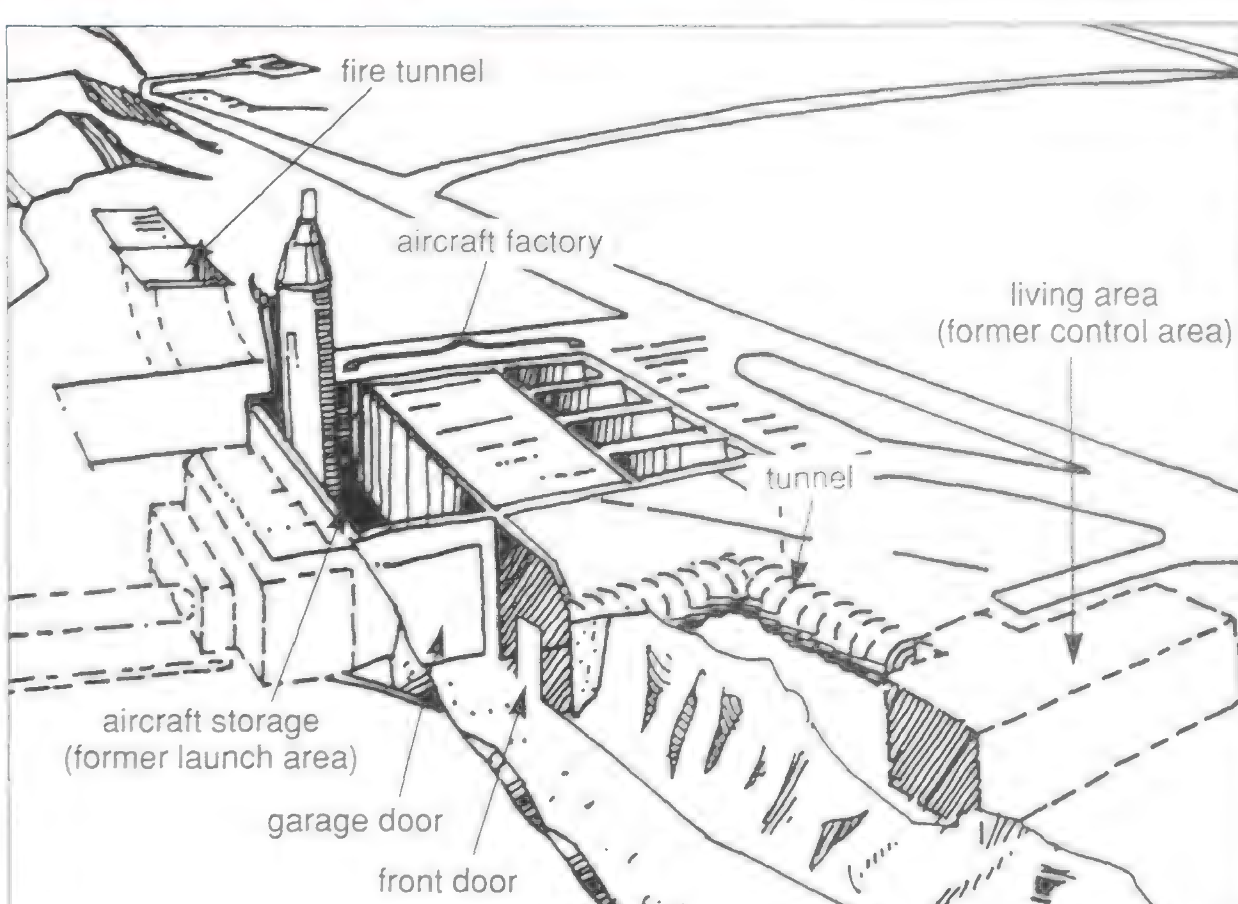
Inside the control room, lime green paint created a gloomy, haunted feel, almost as if you were in the heads of servicemen ready to start the launch sequence. Morbid souvenir hunters had removed launch buttons from the control desk.

Many of the sites give off an aura of doom, and, like the aura that surrounds graveyards, it inevitably attracts kids. In New Mexico there are "silo clubs"—more accurately, gatherings of young people drinking beer. And stories circulate about dead bodies and ghosts and a silo-dwelling hydra-headed monster—stories that occasionally inspire dangerous stunts. Cass Mason, director of the Department of Public Safety in Hagerman, New Mexico, has been on two rescue missions in the last few years—once when a man fell 40 feet into an Atlas-F, and another when children who were burning old Air Force manuals suffered smoke inhalation. "All the sites have their problems," he says.

Dave and Rose Sigler of Roswell, New Mexico, ran into big ones after they bought an Atlas site in 1991 with the idea of converting the underground control room into a home. Before they could move in, they discovered the site was contaminated with various chemicals—possibly rocket fuel, gasoline, industrial cleaning agents, and other compounds that had been dumped there three decades ago. The Army Corps of Engineers, which is responsible for detecting contamination of former missile sites, has been a continuing presence on the property for five years now.

The Pedens use plenty of overhead lights to make up for a lack of windows.

The fire tunnel was an underground water-filled channel designed to contain the flames from a launch. From fire tunnel to living area, Peden Place spans 340 feet.



ADAPTED FROM USAF ART

"I can't go out and put up my kid's playground because they are out there taking core samples," Dave Sigler says.

Regardless of the dangers, the Pedens' faith in the value of the old missile bases is unwavering. Ed Peden believes that the sites will last until or beyond the next ice age, so the Pedens view themselves as stewards, not owners. "It's part of what we believe," Dianna Ricke-Peden says. "We don't believe in holding on to things."

But they also believed that to feel comfortable in their new home, they needed to hire a medicine woman to perform Lakota Sioux rituals she said would cleanse the negativity left by years of concentrated nuclear thoughts. "She turned the energy of the destructive warrior into the protecting warrior," Dianna Ricke-Peden says. "It was a beautiful experience."

The Pedens tend to talk about warfare in terms of psychological forces; Ed once wrote a poem about his Atlas base entitled "Transformation of Sight," one line of which reads: "The ultimate male ego's warped will." "It's remarkably phallic," he explains; "the missile raises up erect, then penetrates the atmosphere and spews radioactive waste to countries thousands of miles away." The poem ends with a statement that sums up the spirit in which the Pedens approach the transformation of missile silos: "Ancient fears will transform into Love."

In transforming a missile silo into a home, the Pedens have incorporated many of the domestic comforts family happiness has traditionally thrived on. They admit, though, that a lack of sunlight sometimes leads to depression. "We try to plan time outside every day," Ed Peden says. When they do leave, they put on the answering machine so that callers can hear their message: "We must be on the surface just now," it says. "We will inevitably return to our burrow."

Below: Principal Dan Stockstill shows the blueprints of the Atlas base that was transformed into Jackson Heights High School. Bottom: The Pedens fly one of Ed's ultralights over their Atlas estate.

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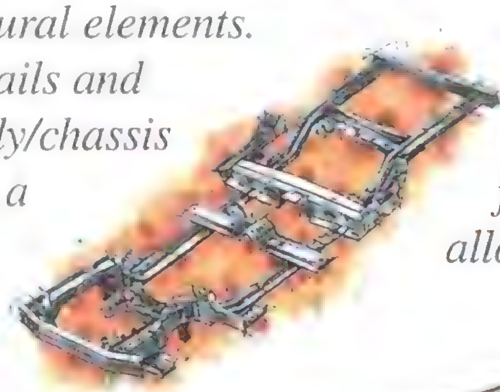

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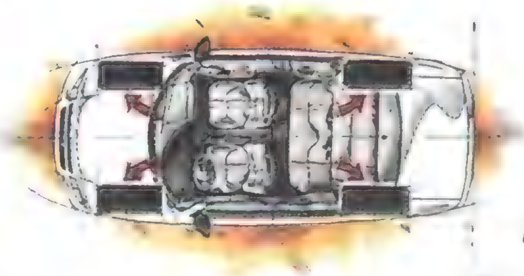

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Going Vertical

Why the straight-up fighter effort broke down.

by Stephan Wilkinson

REFLECTIONS ON THE COLD WAR

One was the riskiest military airplane Lockheed ever built, by the company's own admission. The other "coulda been a contender," in the opinion of the one pilot who successfully flew it. One school holds that neither airplane operated long enough to prove either statement. Another holds that these strange craft flew just long enough to save the U.S. Navy a great deal of money by proving that the concept upon which they operated was terminally flawed.

They were the Tail Sitters—the Convair XFY-1 Pogo and the Lockheed XFV-1—and in the mid-1950s their half-lives flickered, flared, and faded in a matter of months. They were prototype point-defense interceptors intended for the Navy, and their sole virtue was that they didn't need a runway. The XFY-1 and XFV-1 were designed to perch on their tails, like malevolent lawn darts, and take off straight up, obedient to the howling thrust of enormous contra-rotating propellers.

Helicopters do much the same thing. Unlike helicopters, however, the Tail Sitters eschewed the complications and performance limitations of rotor blades, which must hinge, twist, and flex to simultaneously act as lifting and thrusting surfaces in forward flight. The Tail Sitters transitioned from helicopter to airplane by simply pushing over from the vertical ascent to conventional horizontal flight.

Then their stubby wings came into play, and the contra-rotating paddle blades went to work purely as huge thrusters, powering the Pogo (and theoretically the XFV-1) to…well, not F-104 speeds, but at least 575 mph. These airplanes were never intended to be air-superiority dogfighters but bomber killers, rising like angry wasps to protect their ships. Rather than range, loiter time, or supersonic speed, they needed—and ostensibly had—the ability to report for duty with the alacrity and accuracy of a well-aimed five-inch cannon round.

All well and good, but now we're humming along in a Tail Sitter in level flight, mission accomplished. The target is history, the guns are empty, the fuel tanks are reaching that state, and it's time to land—in a Tail Sitter, the procedure that separated the men from the boys.

A Tail Sitter returning to base had to again "go vertical"—translate from high-speed horizontal flight to a nose-up hover—and then reverse course, backing down to a landing. This required the pilot to judge his attitude, altitude, and position over the ground while lying on his back and looking over his shoulder as he worked

With its 5,850-horsepower turboprop engine and two 16-foot contra-rotating propellers, Convair's vertical-takeoff-and-landing fighter prototype could leap straight off the ground, earning it the nickname Pogo.

NASM (4)


NAVY
NAVY

NASM

Pogo test pilot "Skeets" Coleman (above and at left) and flight test engineer William Chana (far right) felt that trying to land by looking back over your shoulder demanded too much of the pilot. At one time they envisioned flying the Pogo from a prone position so the pilot would be standing upright for takeoff and landing.

the throttle and flight controls to set up a controlled descent to what in real life might well be a rolling, pitching, crowded ship's deck.

"Takeoff was very easy," recalls James F. "Skeets" Coleman, an ex-Marine fighter and dive-bomber pilot who was the XFY-1 project test pilot. "You can trim up an airplane fast on takeoff." We were sitting in the shade of a dusty hangar on Brown Field, on the Mexican border south of San Diego, very near the concrete ramp where Coleman had first flown the Pogo through its entire routine. Once a Navy auxiliary field, today Brown is home to sun-bleached Cessnas, tired Pipers, and the Experimental Aircraft Association chapter for whom on that Saturday Coleman and his girlfriend had volunteered to make lasagna.

Coleman, now 72, has the worn face of a long-ago prizefighter, but he is a charming and gentle man with an easy laugh. He smiled as he looked back 40-some years to a time when his Marine Reserve greens still fit snug, when he was a test pilot with an aeronautical engineering degree and dreams of someday building and marketing his own flying automobile. "But landing...," he shook his head. "When you came in and pulled it up into the vertical, you were faced with three different configuration changes at the same time, all the time trying to figure out when to add power since you didn't want to zoom up too high, because you had a hell of a time backing down.

"When you pulled up, you had to rotate your seat—it moved from the normal in-cruise position to a setting that put it about 20 degrees up from the horizontal when the airplane was straight up. So you have a seat rotation change, a trim change, and a power change, and at the same time your attention goes from your instrument panel to looking down back over your shoulder, because you can't fly the thing and follow the instruments. Jeez, I still have a stiff neck from that," Coleman says with a laugh, shrugging his shoulders like a wrestler working out a kink.

The terrible danger, however, was that at a descent rate of greater than 10 feet per second, the airplane would suddenly tumble, totally out of control, most likely at an altitude too low for successful ejection. (It had already happened to a Pogo model in a wind tunnel.) The irresistible temptation was to play it safe: hover, even climb. But the higher you climbed, the more you had to work at backing down. And the farther off the ground you were, the more difficult it became to judge vertical speed and altitude. "Standing still at 500, 600 feet, I lost my depth perception," Coleman says.

Coleman had practiced by flying every helicopter the Navy would provide (he was by that time a civilian with a commercial helicopter rating). "These Navy helicopter guys would tell me they could hover at 500 feet and know whether they were going up or down, so I said, 'Fine, let's mask off your rate-of-climb and altimeter.' And they couldn't do it."

He learned to fly the Pogo in hover inside an enormous blimp hangar at Moffett Field, near San Francisco, while the airplane was tethered to keep it from straying too far. The main cable was attached above the propellers, and a winch operator stood by to jerk all the cables tight, suspending the Pogo like a badminton birdie on a string.

"My call was...'Catch me—*catch* me,'" Coleman later wrote in a report on those tests, "...and I had to call him a lot." The team eventually realized that the Pogo was being batted around by its own turbulence—a rotating doughnut of downwash, its own prop blast confined and cycled by the hangar walls. Coleman took the airplane outdoors for its first untethered tests.

Still, flying the Pogo in hover required a pat-your-head/rub-your-belly knack. "Here, let me take you for a hovering flight in a Pogo," says William F. Chana, today 75, who had been

a Pogo flight test engineer. "Here's your control stick" (Chana hands me a pen) "and put your feet on the rudders. You're in the air, in a vertical hover. Okay, now, if you want to transition forward, what do you do?" I push the stick forward. "Right. Transition aft?" I pull the stick back a bit. "Okay. Transition to the right."

Coleman has already told me that the rudders controlled side-to-side movement when the airplane was vertical, so I step on a make-believe right rudder pedal.

"Okay. To the left. Okay. Now let's get back to neutral. Now let's transition 45 degrees to the left." Baffled, I poke the stick to the 10:30 position. "No, don't tilt the nose, stay in hover…no, you're not going that way…you gotta use some rudder and some forward stick. It's confusing as all hell…. You cannot fly the airplane unless you have 50 hours in the Moffett Field tether."

In the late 1940s Chana and two other Convair engineers had for the fun of it built the WeeBee, a tiny, 30-horsepower miniplane, in an attempt to fly the smallest airplane that could carry a pilot. The media inevitably called it "the world's smallest airplane" (and indeed it was, if you consider weight rather than wingspan). But what particularly interested Chana was that he flew the WeeBee while lying prone on the outside of a flat-topped fuselage, which was the size of a locker room bench. If you could fly a WeeBee while lying on your stomach as though you were doing a belly-whopper on a Flexible Flyer, why couldn't you fly a Pogo the same way?

Coleman spent 50 hours mastering vertical ascents and descents in a blimp hangar at Moffett Field, California, where the Pogo was tethered with cables and pulleys at wingtips and nose to keep it on the straight and narrow. Without those 300 training-wheel flights, a pilot could not safely maneuver the aircraft.

NASM

Déjà Flew

When I was a young pilot, 30 years ago, Skeets Coleman was one of my heroes. He and I worked for the same publishing company. He was the closest thing our company had to a Legend Incarnate—which indeed was basically his job description. Occasionally I even got to fly with him, "copiloting" our company's Commander Shrike twin. Coleman, of course, needed a 200-hour copilot like he needed a third engine.

Now I was sitting in the very same seat that Colonel James F. Coleman, U.S. Marine Corps Reserve, had occupied. Only a handful of individuals had ever planted their bottoms on the battered aluminum seatpan of the Convair XFY-1 Pogo, and I became one of them during a visit to the Smithsonian Institution's Paul E. Garber Restoration, Preservation and Storage Facility in suburban Maryland. Had I been alone, without an anxious curator looking over my shoulder, I'd have made turboprop noises. "RRRrrrooowwwwerrrr, mmmwaaahhhh…Roger, going vertical, stand by for condition check…getting a red light…gearbox temperature in the red…negative, I'll stay with the ship…."

The XFY-1 is inside a warehouse, one of a warren of pinkish-beige industrial buildings at the facility, which is home to 40,000-odd aircraft, engines, spacecraft, and artifacts awaiting their day in the gallery spotlight. They are parked, piled, and filed, jammed together wingtip to rudder, prop blade to heat shield, America's aerospace history still redolent of the sweat of its pilots and the reek of its fluids.

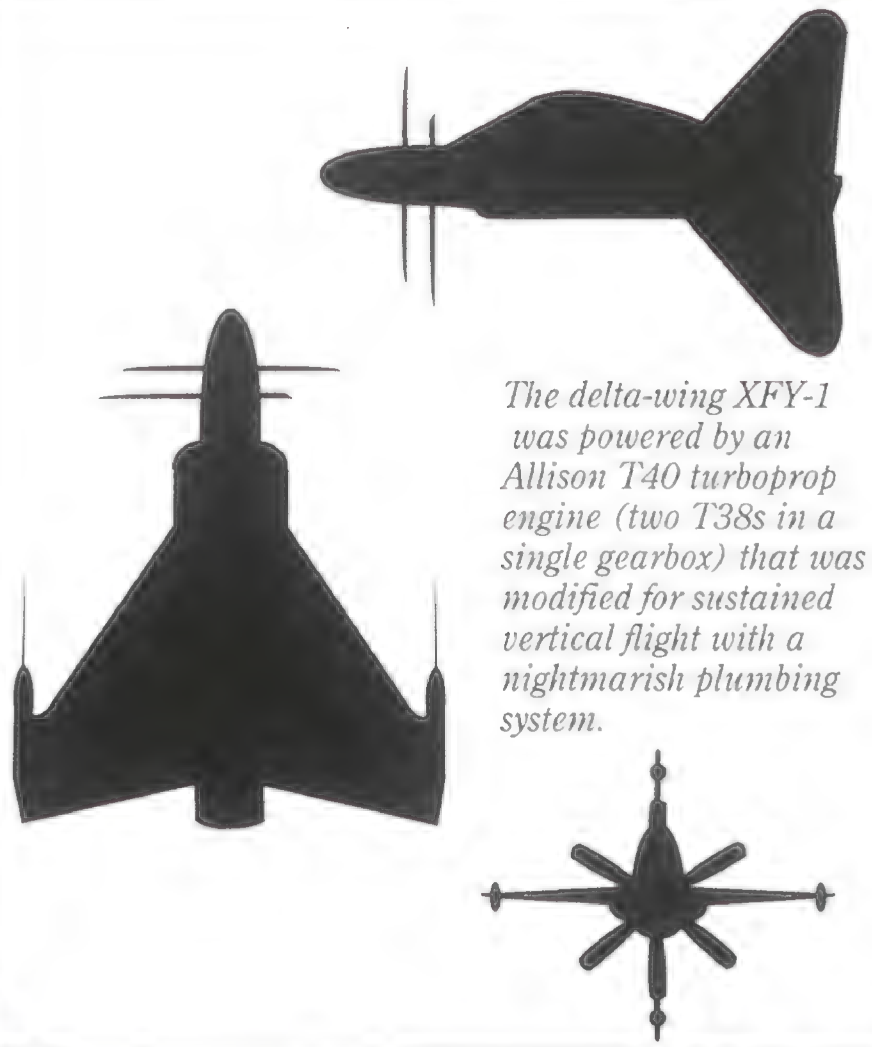
The Pogo is dirty, covered with bird droppings and grime. The battered cockpit belies the fact that this is the aerial equivalent of a '50s Cadillac convertible with only 500 miles on the odometer.

I wrap my left hand around the power lever, its knob the size of a can of orange juice concentrate. I'm surrounded by steam-era gauges that once plumbed every delicate life support system of a pair of engines and a gearbox anxious to turn into a huge satchel of grenades. On the panel is a big red light labeled "camera tattle," which I assumed glowed whenever the cockpit film began to roll—those were the days before downlinked data.

Feet hard against the rudder pedals, I scootch myself far enough up the seatback to imagine that I am sitting on a parachute pack. Yet it is impossible for me to get my mind around the concept of half-sitting, half-lying in this seat, the enormous contra-rotating propeller blades thrashing around above me, the Pogo's nose pointed at heaven.

Better you than me, Skeets.

—Stephan Wilkinson



The delta-wing XFY-1 was powered by an Allison T40 turboprop engine (two T38s in a single gearbox) that was modified for sustained vertical flight with a nightmarish plumbing system.

"Skeets and I put a chair on the hangar floor at the tip of the Pogo's vertical tail," Chana recalls, "and I stood on the chair and just envisioned possibly flying it from that position." Chana saw that a vertical landing with the pilot in what would then be a standing position would be a lot easier than the neck-wrenching dentist-chair job Coleman had until then been doing. "I presented the idea to Convair, but it was too late in the Pogo's development to consider it," Chana says.

"If the program had gone faster, if we had come up with a couple of backup pilots, we would have had a good airplane," Coleman insists. "Because the more I flew it, the more I knew I could have put that thing down on a dime.

The Convair XFY-1 logged a total of two hours and 21 minutes in its six untethered flights. In 1954, Coleman won the Harmon Trophy for making the first airplane flight that took off vertically, transitioned to conventional flight, and returned to a vertical landing.

"We tried to check out John Knebel, my backup pilot, but he nearly destroyed the airplane. He couldn't help feeding in aileron, and soon he's twisting and turning up there. I finally got him down near the ground and got him to take out some of the cross-pad movement and said, 'Land it, Johnnie, land it!' He knocked a couple of the wheels off. We had to tell him to drop it, because he was over by the Ryan factory [at Lindbergh Field, Convair's San Diego base], and there were a lot of people out there watching him." Knebel, an experienced test pilot, wouldn't have had such problems had he spent 50 hours flying in a tethered rig, as Coleman had, but he hadn't had that chance.

Lockheed's Tail Sitter, the XFV-1, flew a lot more but accomplished somewhat less than Convair's, which ended up making six untethered flights for a total of two hours and 21 minutes. The XFV-1 never took off or landed vertically, instead flying its 23-hour flight test program from conventional runways, trundling along on stalky temporary landing gear that looked as though it had been borrowed from a biplane, complete with 1930s wire crossbracing. "We were able to do a lot of flying without putting the pilot in that jeopardy," says Ernest Joiner, today 78 but then, when he was the XFV-1's head flight test engineer, "just a kid."

Because of the Convair's deep ventral fin, "they couldn't do what we did—attach a somewhat conventional gear and put the airplane in the air—so we got a lot of information on the engine installation, how the airplane flew, and how all the systems worked," Joiner says. "I always felt the concept was flawed. To expect a pilot to be able to look down back over his shoulder and maneuver and land that thing confidently...it was a dumb idea."

The XFV-1 was something of an embarrassment to Clarence "Kelly" Johnson, the legendary Lockheed engineer who ran the company's experimental Skunk Works. Johnson is said to have once given a speech in which he enthused about the Tail Sitters as the first generation of an ever more capable vertical-takeoff-and-landing class of aircraft to come. The next iteration, he predicted, would not only land vertically in forest clearings but would then lower itself to a horizontal position and crawl into hiding among the shrubbery.

Johnson eventually recanted. "We did excellent in terms of cost and weight," Jay Miller quoted him in the authorized company history *Lockheed's Skunk Works*, "but this aircraft was a failure...because we had a bad powerplant, and we couldn't look back over our shoulder when flying the thing and judge height. We could practice [landing] on clouds all day, but this is the only airplane we ever built which we were afraid to fly ourselves in the final tests."

Both Convair's XFY-1 and the XFV-1 used the the new Allison T40 turboprop engine (two relatively proven T38s driving one contra-rotating propeller shaft through an admittedly unproven gearbox), and Skeets Coleman had been able to judge height well enough to land numerous times. But Coleman hadn't much liked the engine either, and it didn't help that Convair was simultaneously testing a large flying boat,

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Odd Man Out

While Convair and Lockheed built their prototype turboprop Tail Sitter fighters, Ryan developed the Vertijet, a research vehicle built for the Air Force solely to study jet-powered transitions from vertical to horizontal flight.

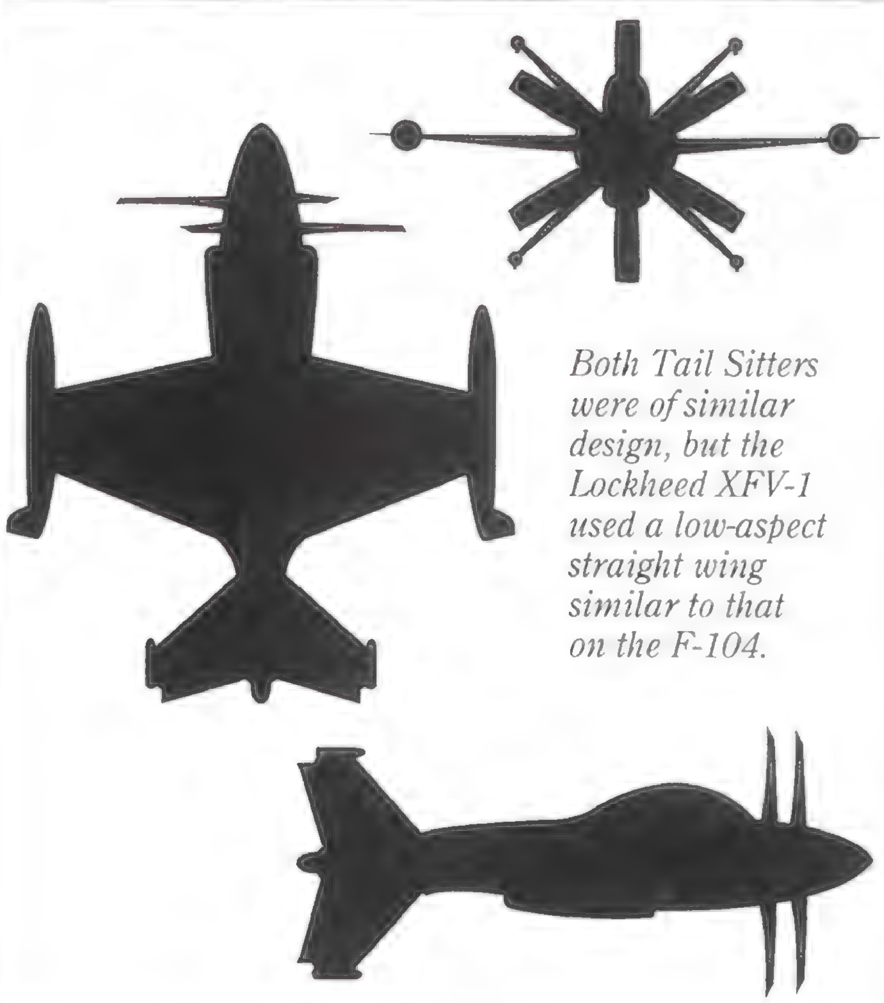
The way Ryan dispensed with the looking-over-your-shoulder problem was to have the pilot "land" by hanging the Vertijet's nose hook on a steel cable strung between two arms on the top of a flatbed trailer. Hovering vertically on the 10,000 pounds of thrust of a Rolls-Royce Avon turbojet, the pilot would cautiously approach the trailer, trigger the cable to swing up and snag the nose hook, and let the fuselage settle against the near-vertical trailer bed, which could be raised and lowered like a dump truck, as it was lowered to the horizontal. In the hover mode, when there was no airflow over the aerodynamic control surfaces, wingtip nozzles redirected engine compressor bleed air for yaw and pitch control, and the pilot's seat rotated forward 45 degrees for visibility.

Ryan test pilot Pete Girard made the first vertical test hop in May 1956, and in April 1957 Girard took off vertically, pitched over to conventional flight at altitude, and returned to vertical for landing. That summer, Girard made eight demonstration flights at Maryland's Andrews Air Force Base and also put on a splashy show at the Pentagon (see "Hedge Hopping," Above & Beyond, Aug./Sept. 1993). But by 1958 funding and interest had run out, and the two Vertijets were relegated to museums.

—Patricia Trenner

COURTESY ERNEST JOINER

Lockheed's Ernest Joiner and local transportation officials came up with creative packaging to protect the XFV-1 on a road trip from the Burbank plant to the airport.



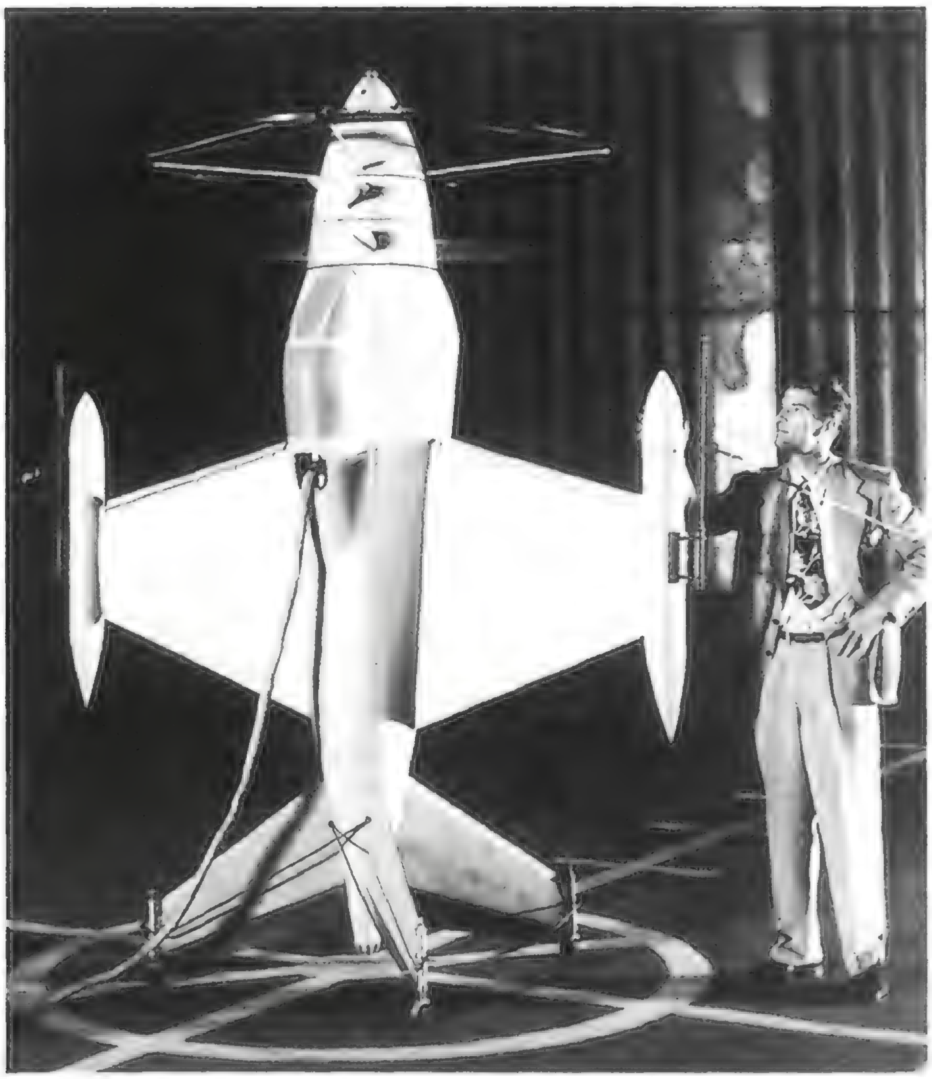
Both Tail Sitters were of similar design, but the Lockheed XFV-1 used a low-aspect straight wing similar to that on the F-104.

the R3Y Tradewind, that used four T40 engines—or, to put it another way, eight paired T38s. "I heard from the test crew that on one flight of the R3Y they lost seven out of the eight," Coleman says. "That was worrisome, because on the Pogo, you'd have had no choice then but to blast out" if you lost even one.

Lockheed was initially encouraged by research that the National Advisory Committee on Aeronautics had conducted on a one-quarter-scale radio-controlled vertical-takeoff-and-landing model, but of course nobody needs to look back over their shoulder when landing a radio-controlled model. In the real world, however, the XFV-1 evinced a trait that didn't seem to bother the Convair Pogo, perhaps because the Pogo had large, highly swept delta wings while the Lockheed prototype had what were essentially stubby F-104 straight wings: When transitioning from horizontal to vertical flight, the XFY-1 was unstable.

Lockheed's test pilot for the project was Herman Salmon (stuck for life with the inevitable nickname Fish). He was a handsome, mustachioed, freewheeling Errol Flynn lookalike, not an engineer but a former barnstormer.

In an interview published in Steve Ginter's *Naval Fighters: Lockheed XFV-1 VTOL Fighter,* Salmon said, "[A] shallow transition was considerably different than the easy process of going vertical from a zoom climb. As you would slow down and pull up...about the time you hit 30 degrees and 60 mph, she'd want to start to roll and be quite unmanageable. At that point the propwash was being deflected [due to the extreme angle of attack] and you weren't flying on the wing anymore, and the airplane was really stalled. Things would get progres-



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sively worse until you came to about 80 degrees, almost vertical, and then it would become quite easy to handle again."

Salmon was widely admired in the test pilot community, but he was never allowed to master the XFV-1. "We finally concluded that it was just foolish to risk the pilot's life with the lack of reliability that the engine/propeller combination had shown us," Joiner says today. "I had to write the letter to the Navy saying 'Dear Navy: We'd like to quit this program.' No, we didn't say 'Hey, Navy, this whole idea is too stupid to continue,' but I thought it was a flawed concept."

In at least one sense, Salmon, who died in 1980 in the crash of his Super Constellation, made out better than Coleman. "Fish Salmon got a big bonus, and he never even took off or landed vertically," Coleman says. "Yet he made $15,000. He said to me, 'You're dumb, Skeets, you're dumb.' I got $2,000, as I remember. But he was a character."

We may never see the Tail Sitters' likeness again—at least not with a human pilot in the cockpit. (And a good thing too, say some strategists and engineers.) It was a project that found eager support only during what one aviation writer has called an era of "technological euphoria." Anything seemed possible in light of the incredible power of the turbojet engine and the dawn of supersonic flight. During the late 1940s and early '50s, airplanes had been flown with tails and without, with triangular wings, wings that moved, wings that looked like backward ironing boards, doughnuts, and flying saucers, and barely any wings at all. Pilots had flown lying down and standing up. Engines had been buried in every cranny of an airframe's structure—there were ramjets, jet seaplanes, even jet airliners.

The Germans had already done a great deal of work on VTOL interceptors to attack bombers when the Reich no longer had many airfields from which to launch conventional fighters. The Focke-Wulf Triebflügel was the most notorious: It had three huge wing-like rotors that free-wheeled around the fuselage under the drive of vectored-thrust ramjets at their tips, but it never actually flew. Only the Bachem Ba 349 Natter made it into the air. The Natter was a primitive rocket plane launched from a vertical rail. Unfortunately, it had no landing capability. "I'd hardly call the Natter a VTOL," says military aviation writer Bill Sweetman. "It was more of a VTOLIIBP—Vertical Takeoff and Land In Itty Bitty Pieces."

"With the advent of gas turbines, it became

JOE GOSEN

COURTESY ERNEST JOINER

A one-quarter-scale wind tunnel model (above) gave Lockheed a leg up on learning the tricks of maneuvering a VTOL fighter.

Ernest Joiner (right) was head flight test engineer on the XFV-1 in 1954. Today (right, top) he says that Lockheed did its homework on the powerplant. "We gave it a chance to foul up without putting the pilot in jeopardy," he recalls.

Because the only Allison engine modified for continuous vertical flight went to the Convair VTOL, the Lockheed Tail Sitter got temporary landing gear that enabled conventional takeoffs and landings. Lockheed was able to log much more flight time than Convair, but the XFV-1 never landed or took off vertically.

U.S. AIR FORCE FLIGHT TEST CENTER HISTORY OFFICE


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has been a VTOL Mafia in the Navy that is trying to do VTOL and is extremely optimistic in their outlook. You can make VTOL look awfully damn good on paper, until you try to do it in real life."

Apparently, the Tail Sitters looked good on paper. According to Spangenburg, "The Navy did a great deal of study work leading up to the Tail Sitters, trying to justify some place to use them—how in hell to use VTOL now that you were able to do it." So VTOL was an answer looking for a question? "There has always been a faction that said 'Let's do VTOL just because we're able to do it,' without any real regard for service utility," Spangenburg says. "The study concluded that the best justification for the Tail Sitters would be as a 'convoy fighter,' where you could put one on a merchant ship and if the convoy was attacked the fighter could take off" and beat back the threat.

Skeets Coleman would disagree. He traces the genesis of the Tail Sitters back to the stunning impact of the Japanese kamikaze threat. "The Navy took a real beating from the kamikazes," Coleman says. "The carrier was really threatened. The Air Force was calling them sitting ducks no matter how many airplanes you put on 'em.

Lockheed's transporter-launch trailer, like Convair's, enabled the fighter to take off from anywhere a jeep could tow it (above).

"The philosophy was to put the airplane on the back of any ship, under a teepee, so you'd have a line to intercept any airplane coming toward the carrier fleet," Coleman says. "It was never intended to replace the carrier but to give it a picket-line type of fighter protection."

"The idea was to spread your air power around, among a number of smaller ships rather than on one or two huge, vulnerable aircraft carriers," said John Fozard in an interview before his death last July. From 1963 to 1978, Fozard was the chief designer of the Harrier, the British jet-powered VTOL effort that began as the Hawker P.1127 in 1957 and culminated with the McDonnell Douglas AV8B Harrier II, ultimately the only VTOL fighter to be produced. "Carriers are hard to sink, that's true, but if you can hit one hard enough that it develops a 10- or 12-degree list, your principal weapon—the aircraft—becomes useless."

Still others say that the Tail Sitters arose—excuse the pun—from the Navy's sense that tactical nuclear weaponry had made it impossible to ever again marshal World War II-size task forces—that now our forces would have to be dispersed so that no single bomb blast could take out an entire carrier battle group. "I don't recall ever hearing that justification," says Spangenburg.

possible for the first time for a fighter-type aircraft to actually have an honest-to-God thrust-to-weight ratio greater than one," says George Spangenburg, a retired civilian Navy employee. "The recips couldn't do it." That ratio is the reason modern jets can not only climb straight up but also accelerate simultaneously—they have many more pounds of thrust than pounds of weight—and it's the reason a Tail Sitter could jump straight off the ground.

Spangenburg, today age 84, is a legend in naval aviation. "He essentially took contractor proposals and analyzed them for both cost and performance," says Robert Heisner, an ex-Navy fighter and test pilot and former commanding officer of the Patuxent River Naval Air Test Center in Maryland. "He was the guy who would tell the Navy what this or that widget would likely cost and do—or not do—without regard to the contractor's marketing hype. He was very good. His numbers were so close that some people accused him of having moles inside the contractors' shops, which of course wasn't true."

Spangenburg was never a fan of the vertical-takeoff concept. "Ever since I've been in this business," he says, "there

COURTESY ERNEST JOINER

Whatever the justification for the Tail Sitters, one real-world problem made it impossible to use them as individual sentries standing guard out in the nautical boonies. Airplanes—particularly complex turbine-driven fighters—need an enormous amount of coddling. Every merchantman and frigate that carried a Tail Sitter would also need a crew of mechanics, armorers, avionics technicians, and specialists trained to launch and retrieve it. "In the real world, it just doesn't make sense," Spangenburg says.

"Maybe they just thought, 'Well, we'll see if this thing works, and if it does, we'll figure out [how to support it],' " Lockheed's Ernest Joiner says. "But I don't see how it ever could have worked. I hate to say that," he adds with a laugh, "because it was a lot of fun to do the program."

For military missions, VTOL aircraft suffer from another show-stopper as well: you cannot overload them. Once you have optimized a design so that it can take off straight up and no other way, adding extra fuel, bombs, missiles, guns, and ammo produces a very expensive, noisy, ground-hugging cockpit cooling fan.

That's the beauty of the Harrier, John Fozard explained. "The way aircraft are operated in real life is not VTOL but STOVL—Short Take-Off and Vertical Landing," he insisted. "You have to be able to overload them to a point where they can no longer make a purely vertical takeoff." Harriers, in fact, fit into a category called "flat risers": Once festooned with drop tanks, bombs, and missiles, a Harrier must trundle briefly down a runway or flight deck like a charging razorback before the combination of wing lift and downward-vectored jet exhaust thrust can urge it aloft. A true vertical takeoff is part of a Harrier's repertoire only at airshows, when the airplane is light and hardly combat-ready.

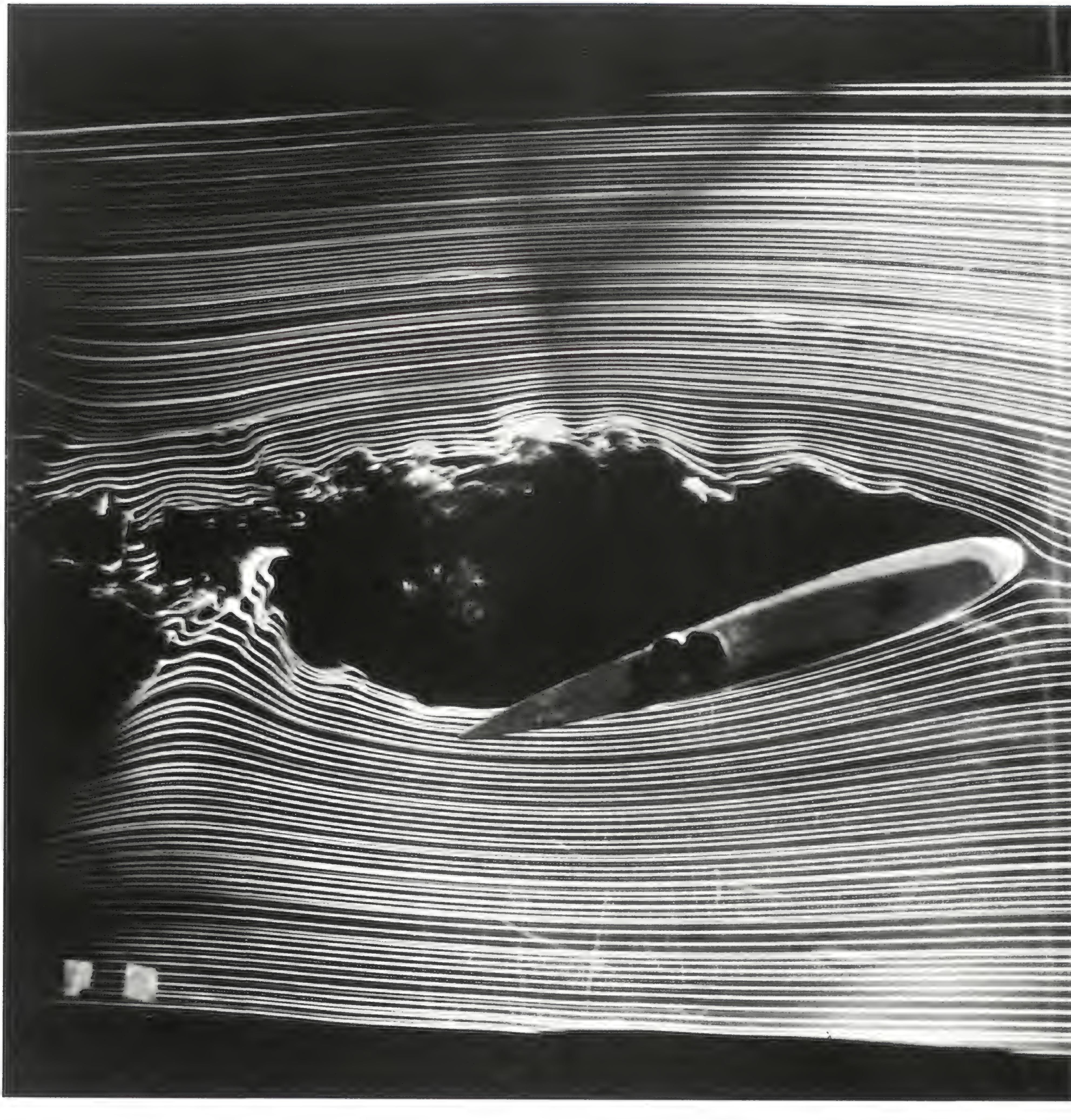
"The Tail Sitters were a passing phase because they were inevitably payload-limited," Fozard said. "Being able to use wing lift as well as jet lift is the key, and we didn't even appreciate how important that was at the time we were developing the P.1127." The now-familiar configuration and rotating-nozzle, vectored-thrust powerplant of the P.1127, which led to the Kestrel and then the Harrier, was laid down two years after Lockheed and Convair pulled the plug on the Tail Sitters program, citing engine and gearbox problems they had experienced.

In 1954, James F. Coleman was awarded the Harmon Trophy for serving as the first airplane pilot ever to accomplish a vertical takeoff, transition to forward flight, and change back to a vertical landing. What was never said is that Coleman was one of the last people ever to venture aloft in a machine that nobody knew how to fly, that no simulator had proved would fly, and that no computer could promise would be controllable.

GEORGE HALL / CHECK SIX

Lockheed test pilot Herman Salmon (center, above) reported that the XFV-1 proved unstable in the transition from horizontal to vertical flight. Two years after Convair and Lockheed threw in the towel on the Tail Sitters, Hawker drew up the configuration of the Hawker P.1127, which culminated in today's jet VTOL Harrier (right).

OUT OF THIN

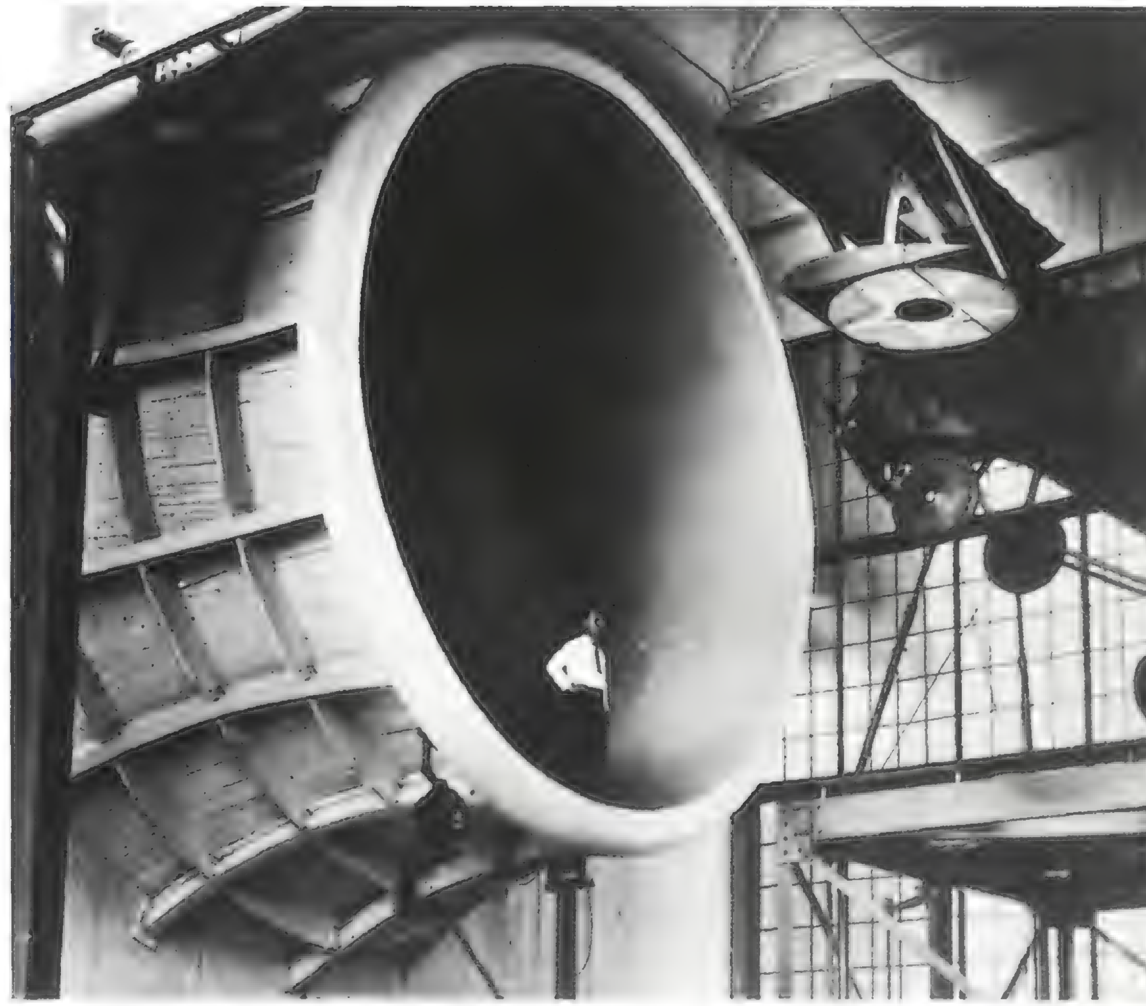


AIR

The fine art of flow patterns.

Smoke-flow visualization, a time-honored wind tunnel technique, shows airflow at 100 feet per second around an airfoil at an 18-degree angle of attack—and the onset of a stall.

ALL PHOTOS NASA/LANGLEY



In 1927, National Advisory Committee on Aeronautics engineers at Langley Memorial Aeronautical Laboratory in Virginia put into operation the Propeller Research Tunnel, which used two 1,000-hp diesel engines and a 27-foot propeller to produce a 110-mph airstream. The PRT demonstrated that fixed landing gear and the protruding cylinders of air-cooled engines generated enormous drag, which led to the design of retractable gear and the famous NACA Cowling No. 10.

by Carl Posey

As long as there has been a realistic dream of flight, there have been wind tunnels, and they will probably be with us until we achieve a perfect understanding of how air moves across any surface, at any scale, at any speed. By then, computers will be able to reproduce these conditions, and wind tunnels may become the relics of some ancient backward race. But such perfection is nowhere on the horizon; air remains an inscrutable thing, and its moving parts are both many and invisible. (A new exhibit at the National Air and Space Museum, "How Things Fly," addresses this enigma. See "In the Museum," Aug./Sept. 1996.)

Understanding that one could not comprehend what one could not measure, Sir George Cayley, a brilliant Yorkshireman of the late 18th century, built a five-foot arm that could whip model gliders through the air at speeds of 10 to 20 feet per second—7 to 14 mph. He tested airfoils and wonderfully precocious designs. His 1804 glider model may have been the first heavier-than-air object ever to fly, and the glider he trotted out in 1853 and persuaded his reluctant coachman to ride was the first man-bearing flying machine. Cayley established the fundamental shape of the airplane, a fuselage with a tail and fixed wings. The wings were

Smoke details a vortex generated by a fairing that joins wing and fuselage, or wing-body strake, on a NASA F/A-18, while "tuft-testing"—snippets of lightweight material taped to fuselage and wing—shows local airflow and turbulence.

fixed because Cayley had separated propulsion from lift: A machine could fly without flapping its wings. Had he possessed the internal combustion engine, the license plates of North Carolina might now read "Second in Flight."

Wilbur and Orville Wright, who in 1903 became the first to succeed in powered flight, didn't get to Kitty Hawk on data from a whirling-arm test rig. Following the lead of pioneers in Britain, they built a small, oblong wind tunnel about the size of a coffin and mounted it on a wood frame with a fan blowing air down the channel. In this crude device, they established one of the enduring unwritten equations of aviation: No measurements = no *Flyer*.

The mother of all wind tunnels was built in Germany in 1908 by Ludwig Prandtl, the father of aerodynamics. In the pretty university town of Göttingen, Professor Prandtl constructed the world's first continuous-circuit tunnel, measuring six feet square in the test section. In 1916 he built the technology's paradigm—a closed-circuit tunnel in which moving air was permitted to come to a standstill before being accelerated through a contraction cone, or nozzle, into the test section.

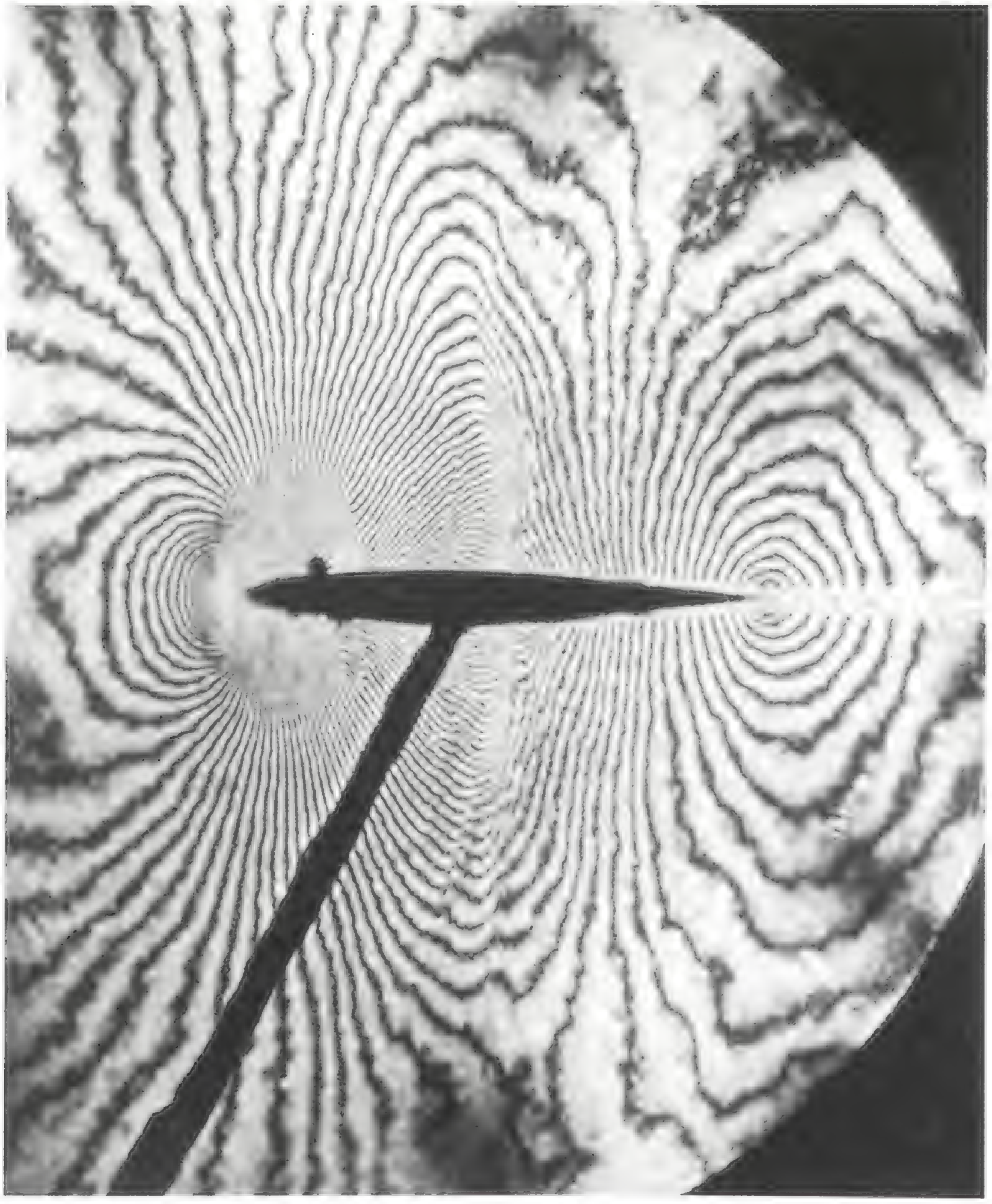
Lockheed used a stainless steel scale model of its F-22 for testing in its low-speed wind tunnel at the Georgia plant. A smoke wand upstream of the model produces vaporized vegetable oil, which in the wind tunnel airstream details airflow through the engine inlets. The technique provides information on how inlet mass flow affects low-speed handling and control surface effectiveness.

Computational fluid dynamics (CFD) enabled National Aerospace Plane researchers to model scramjet engine exhaust at Mach 10. Red-to-pink regions are those of highest air density, including the exhaust area (on undersurface at rear). Contour lines show air density gradients at increasing distance from the surface.

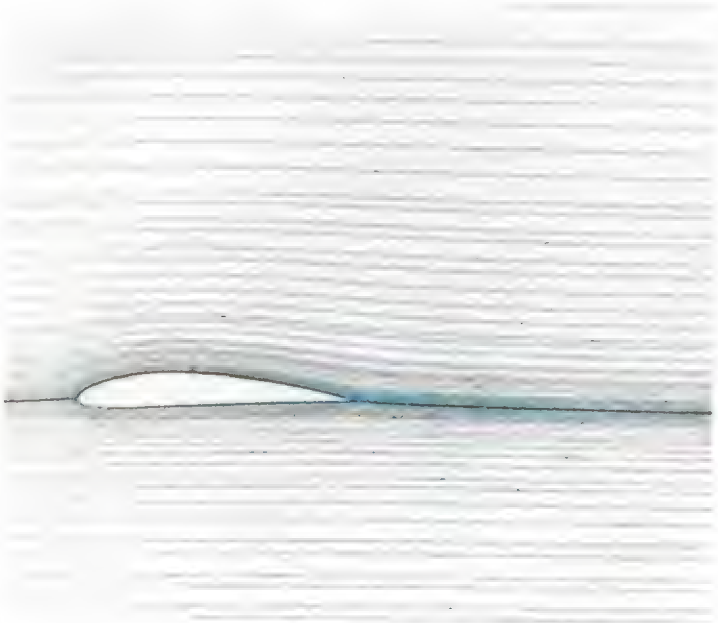
Every major wind tunnel since has followed Prandtl's basic model. Some have been pressurized, some cooled, some built with walls that are louvered to smooth the transition to and from supersonic flow. Some provide a brief pulse of hypersonic wind; a few giants can test full-scale modern fighters. Prandtl would feel right at home working with the 1920s-vintage metal watermelon of the variable-density tunnel at NASA's Langley center in Virginia, or in the giant steel worm at the agency's Ames center in California.

Wind tunnels permitted designers to measure aerodynamic forces, but in their classic form, the tunnels did little to render visible these forces in the eddies, whorls, and burbles they caused. Early fluid dynamicists had done this by working with a much more tractable fluid—water—in which dyes could trace turbulence. Aerodynamicists still use water channels to explore such things as the coarse flow around a model at various angles of attack.

Smoke generators of the type seen on aerobatic performers are used to trace the maelstrom of horizontal twisters dangling from the heavily laden wings of large aircraft in the real atmosphere. Injecting smoke into the airstream of a wind tunnel is a venerable

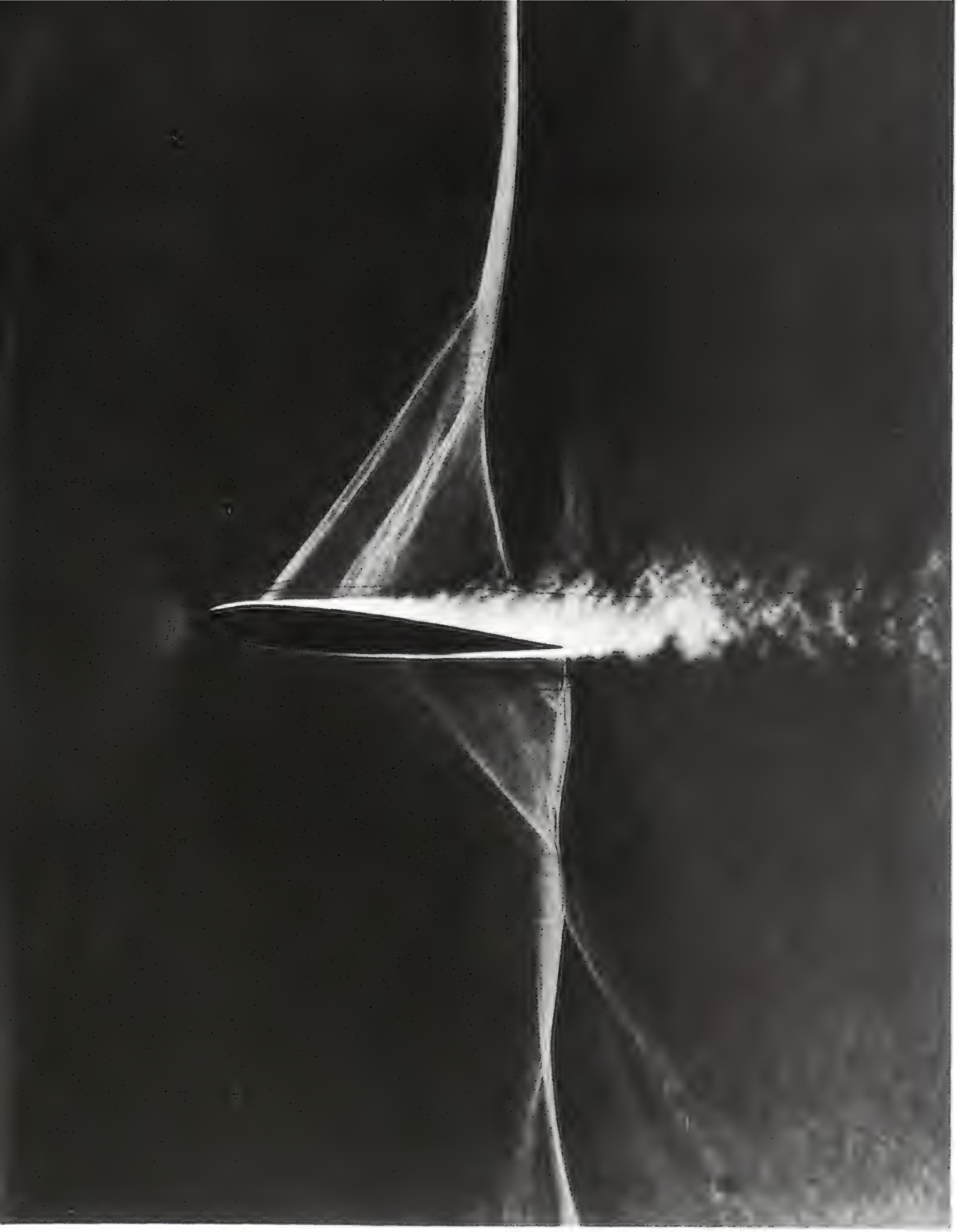


CFD produced the portrait of attached airflow below, in which air is streaming around an airfoil at Mach 0.2. At an angle of attack of 14 degrees, flow separates, and at 25 degrees, the airfoil stalls. Computer modeling is subject to validation in a wind tunnel.



Holographic interferometry flow visualization splits a laser into two beams, one passing through a tunnel test section, the other bypassing it. Recombined on a photographic plate, the beams form a hologram, or interference pattern, that details the density gradients in the test section at that instant. In the interferogram above, density changes appear in a fingerprint pattern.

Ground-based smoke traces an agricultural aircraft's wingtip vortex. Airliner vortices are strong enough to roll smaller aircraft.

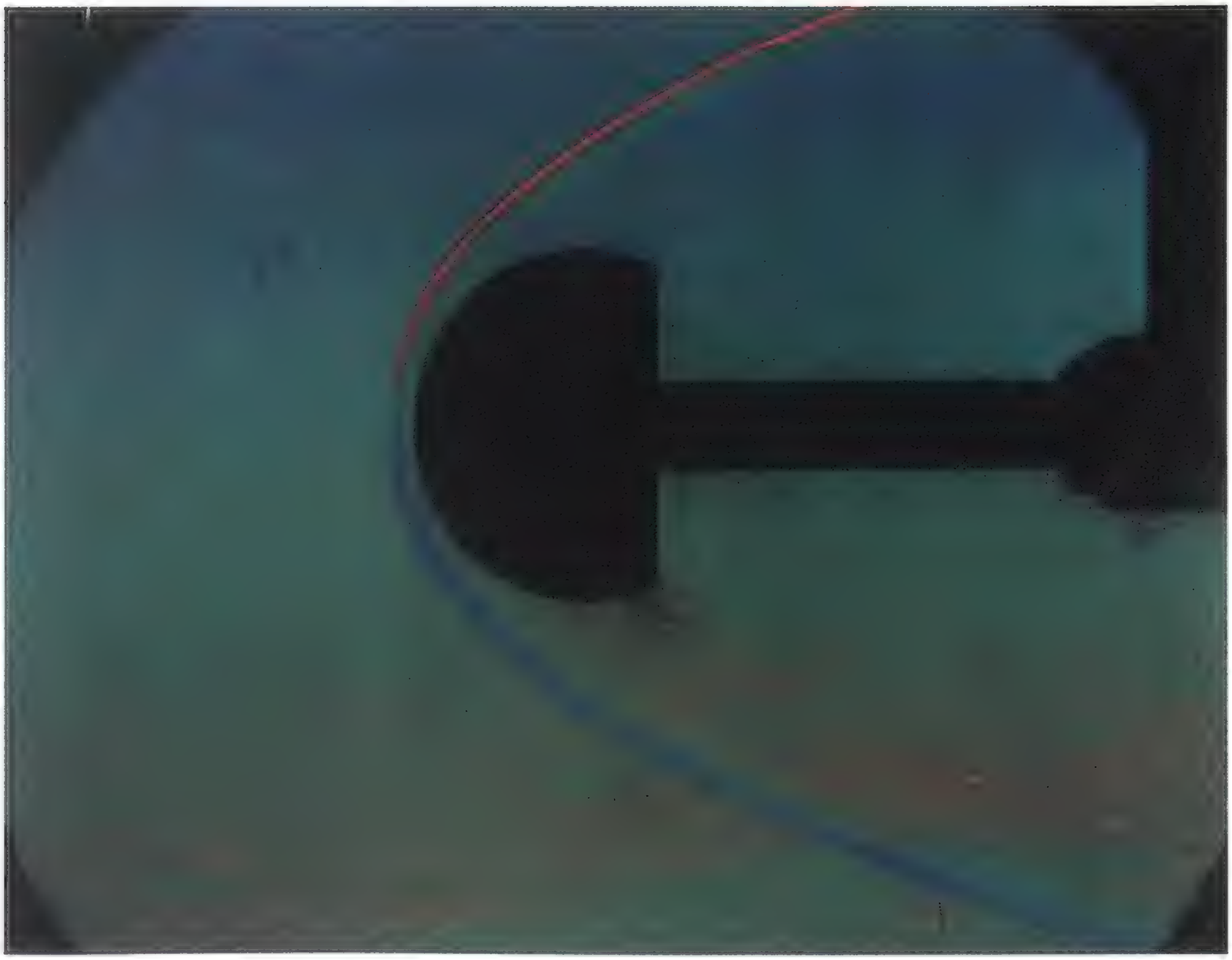


Schlieren (German for "striations") photography detects how changes in air density, produced by shock waves, deflect light rays. Here, transonic flow over an airfoil creates a vertical shock wave followed by boundary layer separation, the archenemy of aerodynamicists.

technique for delineating in detail the airflow across a surface. Tufts of string—on models and full-scale airplanes—also work. They arrange and rearrange themselves to line up with local streams of air, defining airflow the way iron filings define a magnetic field.

Still, these methods are less direct than seeing, especially as the velocities involved begin to be reckoned in fractions and multiples of the speed of sound. Engineers need to look at invisible shocks and separations and all the other demons of high-speed flight. "The human mind is a visual mind," says Dennis Bushnell, chief scientist at the Langley Research Center in Virginia. "We're hunter-gatherers, so we're very good at picking things out that move."

One time-honored method, schlieren photography (German for "striations"), detects how changes in air density, produced by shock waves, deflect light rays. It reveals bow waves and shocks everpresent but rarely seen. Shock waves also appear when a model "flies" through an atmosphere of luminescing nitrogen under a stream of electrons. Holograms, the interference patterns produced by combining disturbed and undisturbed beams of laser light, show fingerprint-like fringing where air density



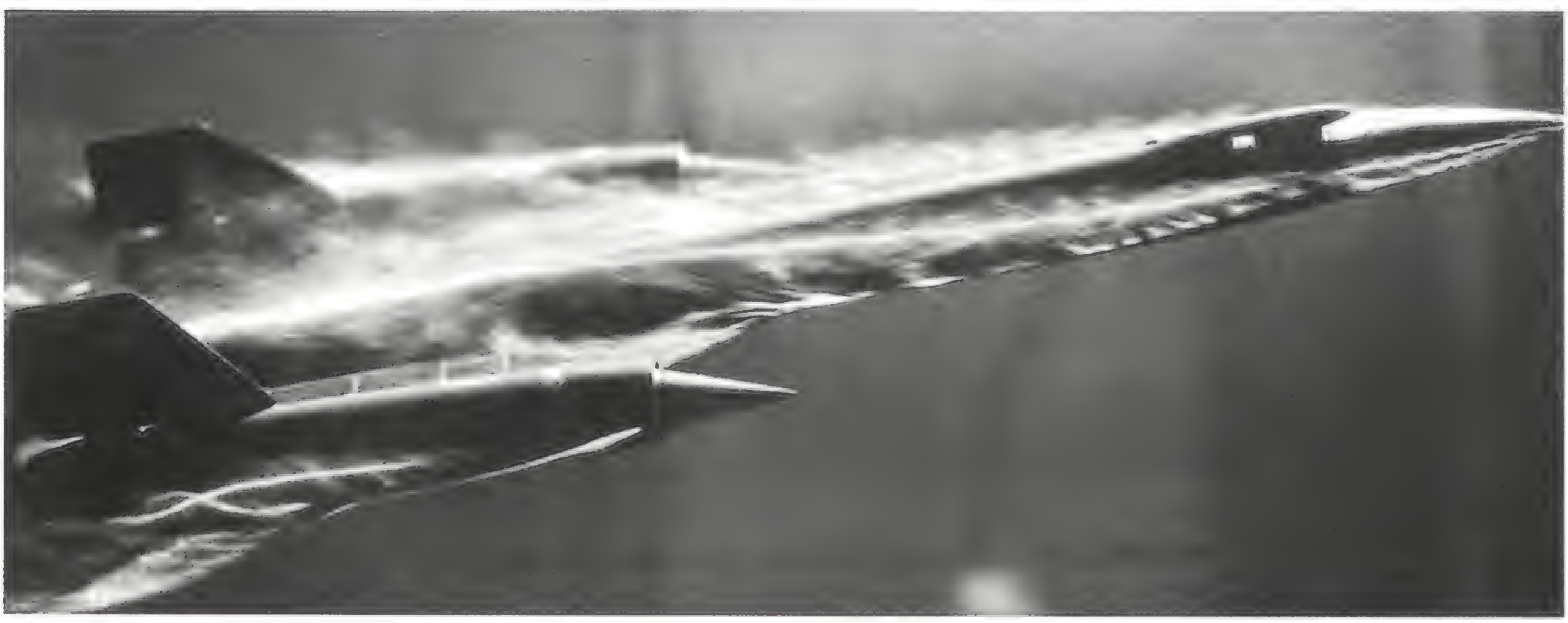
A Small-Scale Atmospheric Entry Simulator showed that a blunt body was the ideal shape for missiles as well as reentry vehicles. For space vehicles, aerodynamicists actually seek boundary layer separation. The strong bow shock wave of a blunt shape dissipates energy far out into the flow field and serves as a sort of natural heat shield.

varies—around an object moving at supersonic speed, for example. Perhaps more important, a hologram scoops up a vast amount of three-dimensional data, securing in a single run what was formerly the work of many.

At one time, each generation of aircraft ate up 10 times more tunnel time than its predecessor. The Wright *Flyer* spent perhaps 50 hours in the brothers' compact tunnel, the DC-3 more than twice that in the tunnels of the 1930s. At the other end of a steeply climbing curve, the space shuttle spent some 100,000 hours in wind tunnel tests. Now the curve has begun to level off.

The bat-shaped B-2, which is pretty much all airfoil, spent only about 8,000 of what John Dahlin, aerodynamics manager at Northrop Grumman's Military Aircraft Systems Division, calls "rigorous wind-on hours in the wind tunnel." Dahlin, who has been with the B-2 program since 1987, says that aerodynamicists leaned heavily on computational methods to "foster the design," bolstered by the venerable YB-35 and YB-49 flying wings of the late 1940s; it

Injecting dye into a water tunnel details wing panel and chine vortices on an SR-71 scale model at a 10-degree angle of attack.



DAVID THOMPSON, DEPT. OF DEFENCE, AUSTRALIA

was helpful, he says, "knowing that there was a solution out there," that bomber-size flying wings were possible. But the B-2 was not in the least an extrapolation from earlier designs. "Aerodynamically," Dahlin notes with an engineer's understatement, "it had a lot to overcome."

According to Paul Rubbert, a Boeing aerodynamicist who worked on the 777's trumpeted computer design, things are changing, but not nearly as rapidly or revolutionarily as one might think. In the early days, he says, designs were tested almost entirely in tunnels, one model at a time: "You'd cut a form, test it, cut another, test it, and keep doing it until it was good enough; then you stopped." Now much of this is done on large computers. "They give us a better understanding of the forces at work and permit us to optimize," he says. "We can turn the problem around and look at it from different angles. So we start with a set of requirements to come up with a few candidate designs. Then we put the result in a wind tunnel."

But the way wind tunnels are used is going to change, Rubbert believes. "From computational to wind tunnel tests, there's an eight-month learning cycle," he explains. "If you want to incorporate those results into the next design, it's another eight months—16 months. We have to increase that learning rate. If you can cycle it in a week, you can push boundaries and push them harder, absorb more risk, and bring the airplane to market quicker and cheaper."

At present, Rubbert finds computers do best when the goal is specific answers to a few specific questions, whereas wind tunnels are key when one needs a massive amount of information. "It takes a day or two to run a simulation on a computer," he says. The startup for wind tunnel tests is considerably more elaborate, but once in the tunnel, "you're getting several answers per second, and many, many different simulations."

One gets more than simulations. Wind tunnels are also studios. Rendering visible the writing of flight doesn't just generate data—it also creates strange, high art.

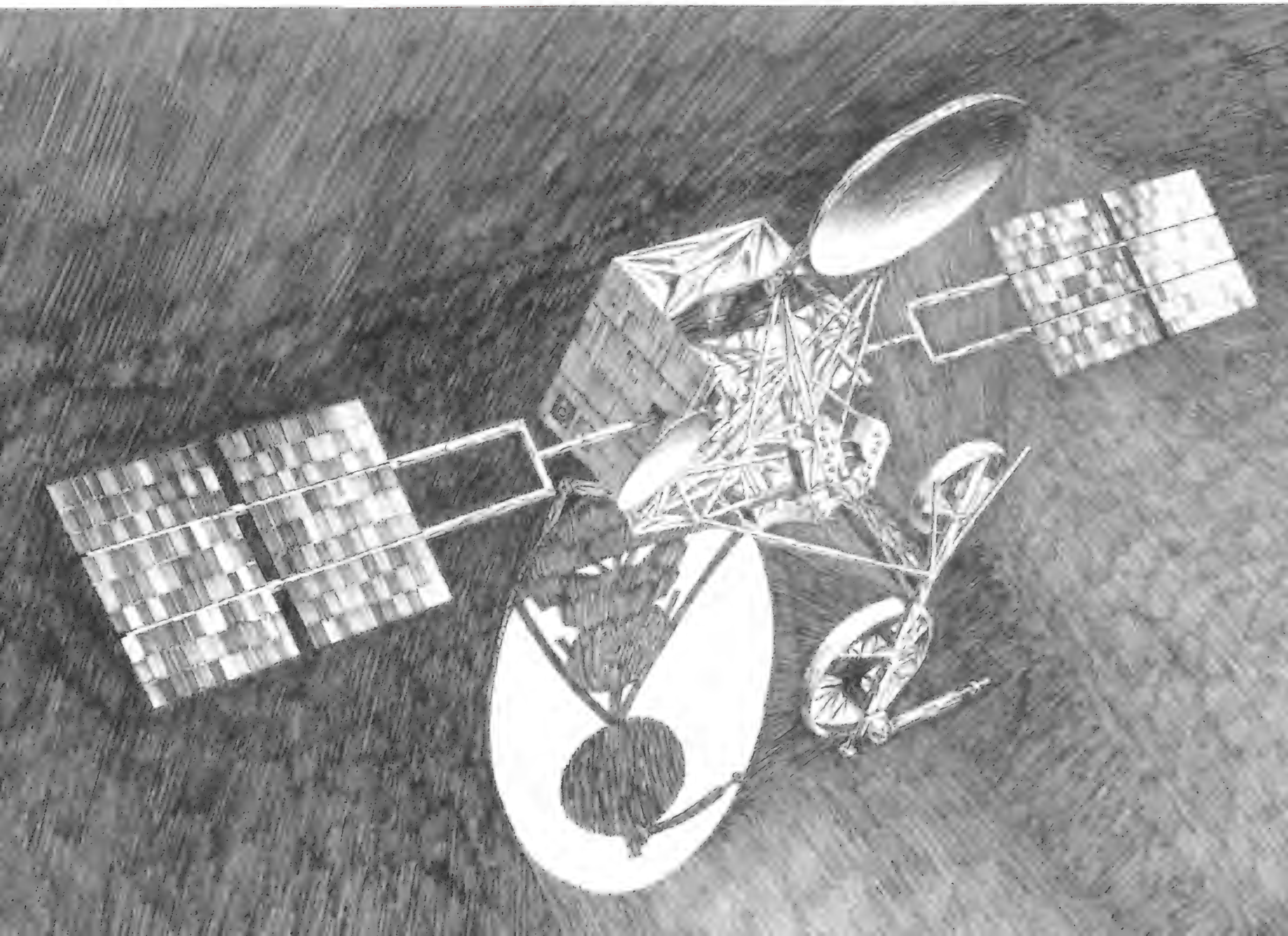
At Mach 20, the shock wave created by a model space shuttle in a 22-inch helium tunnel is made visible by bombardment of an electron beam. Shuttle models have logged some 100,000 hours in 50 wind tunnels.

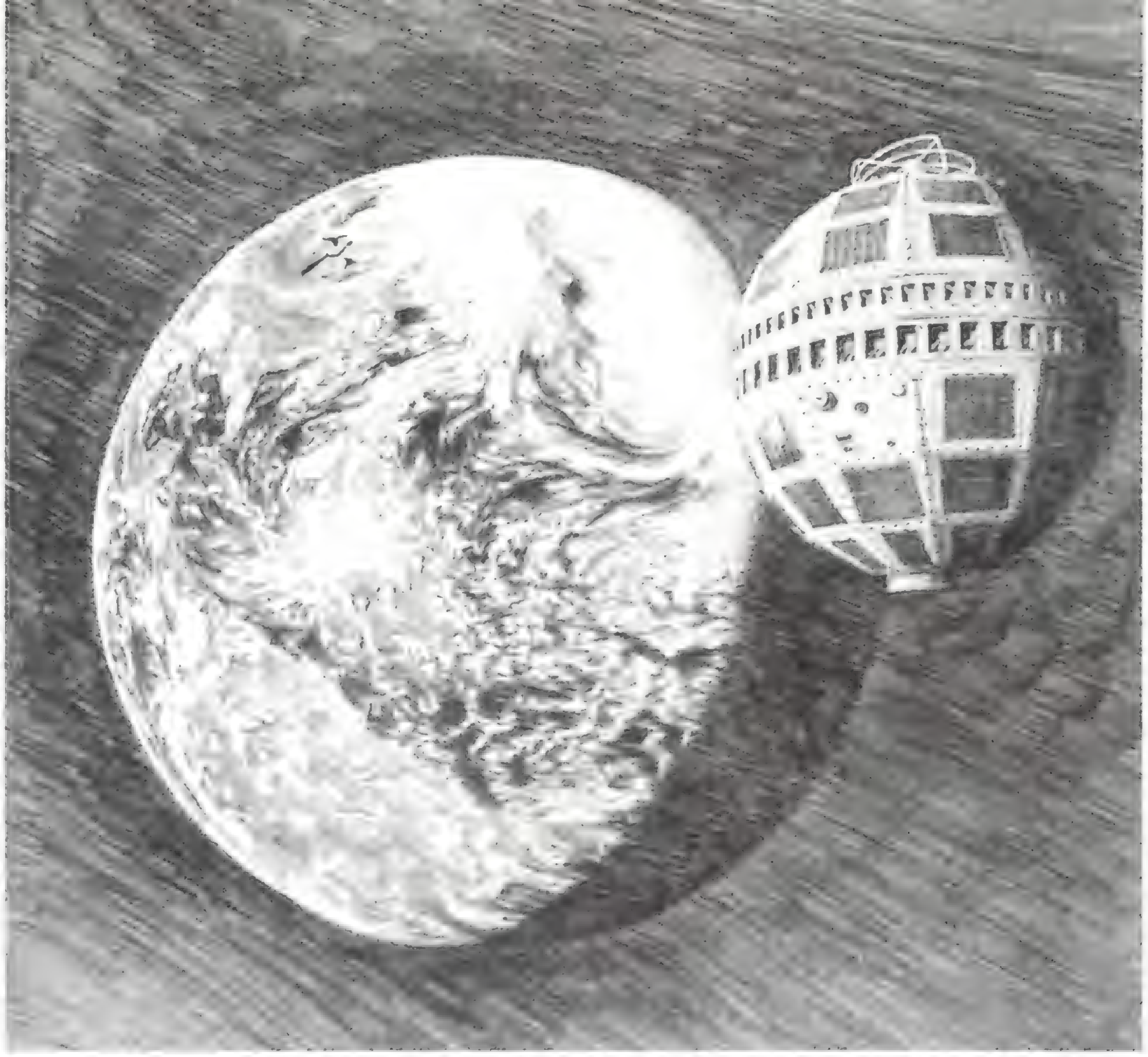
OPENING ACTS

by Frank Kuznik

Illustrations by Carter Emmart

What will we be able to do with telephones, televisions, fax machines, and personal computers ten years from now? NASA offered the Advanced Communications Technology Satellite as a way to try out new services.





Building 55 at the Lewis Research Center in Cleveland looks like any NASA facility—long hallways of cluttered offices done in drab shades of government green—until you step off the elevator on the second floor. Here the decor is a soothing blend of blues and grays, the lighting soft and low, and the setting a weird amalgam of visitors' center, movie set, and electronics sales showroom.

"WELCOME TO ACTS" blinks a sign perched above a series of satellite displays and backlit photographs, advertising NASA's Advanced Communications Technology Satellite program as if it were a new luxury car. A row of picture windows across an adjacent wall looks onto a control center, complete with technicians hunched over a bank of computer screens. Stacks of consumer electronics line an alcove in the rear of the room, featuring state-of-the-art desktop teleconferencing units with built-in video camera and speaker phone. It's a slick sales job. But it makes a visitor wonder why the satellite, if it's so good, has to be sold.

In fact, ACTS is a luxury-model comsat. It's loaded. It carries a suite of electronics designed to increase the amount of traffic that communications satellites can handle, a trend the industry has pursued from the 1962 launch of Telstar, which carried one television and 60 voice circuits, to the impending launch of Intelsat VIII, with four television and 120,000 voice circuits. It carries antennas and processors that make it more versatile than a conventional commercial satellite, even though some comsats have used devices similar to those on ACTS.

"We've had some people say, 'Well, you're flying '80s technology,' and in terms of the individual boxes on the satellite, that's true," says project manager Rod Knight. "It's the overall architecture that is really innovative."

"They can do some really cool things," says Victor Barajas of Hughes Space and Communications, the world's leading producer of communications satellites. "Some stuff, we can just look on in envy."

The road test for ACTS, however, is based not just on what that baby can do, but on whether what it can do helps U.S. industry. It turns out that may be a harder test than some of the physics experiments the satellite has been used to conduct.

ACTS was NASA's response to what many in the United States thought was a slippage in the long-standing American dominance of the communications satellite market. "When NASA canceled the satellite communications program [in 1973], both Japan and Europe jumped in," says Burt Edelson, director of the Institute for Applied Space Research at George Washington University and, between 1982 and 1987, an associate administrator of NASA. "They launched 22 experimental satellites from 1973 to 1992. The United States was getting a smaller and smaller share of the comsat market."

That share has never dipped below the current majority holding, however, and, as NASA discovered when it announced the ACTS program in 1982, industry leaders Hughes, Loral, and TRW were confident of their lead in the market. Those satellite builders labeled the technologies that ACTS was intended to demonstrate either already proven or irrelevant.

"Hughes did everything it could to kill the ACTS program," says Walter Morgan, senior consultant at the Com-

ACTS THE WONDERSAT
The first communications satellite able to transmit a gigabit of data per second, ACTS has demonstrated new uses for satellites in the communications and consumer electronics markets. With a 10.8-foot transmitting antenna, multiple beam-forming networks, and onboard processing, ACTS integrates data, voice, and video services and broadcasts in the Ka-band.

TELSTAR
It weighed 170 pounds and, from its low orbit, was in sight of its ground stations for only 20 minutes at a time. But in 1962 Telstar heralded a new age. Developed by American Telephone & Telegraph, Telstar broadcast with only 3 watts of power and so required massive ground stations, located in Maine, England, and France.

munications Center, a consulting firm in suburban Maryland.

Edelson, who spearheaded the program for NASA beginning in the early 1980s, says today, "It was an absolutely perfect example of what happens when the government steps in and tries to level the playing field. The leader doesn't want the government in there leveling the playing field. They were against it."

From 1982 to 1987, ACTS was routinely scratched from NASA's budget request by Ronald Reagan's administration, which favored a free-market approach, then reinstated by Congress, which supported government-sponsored research. The annual political tug-of-war nearly killed the program. The ACTS launch was delayed five years, and the cost grew from $350 million to $500 million. Finally, in September 1993, ACTS was launched aboard the space shuttle.

Its designers were guided by the knowledge that orbital space and the radio spectrum are both finite resources and subject to growing demand. "Starting in the '70s, we could see that [desirable geosynchronous] orbital slots were filling up," says Ronald Schertler, chief of the ACTS experiments office. "Even after reducing the spacing between the satellites, it was clear we were going to run out of room." By international agreement, satellites using the same frequencies must be kept at least four degrees apart to avoid interference.

Along with physical space, broadcasting space was growing tight. "We were using C-band, which was filling up, and Ku-band was coming along, though with new applications it was clear that was going to fill up too," explains Schertler. With frequencies at a premium, satellite designers have sought to increase the efficiency of the channels they're assigned.

Early comsats broadcast a single beam that illuminated a significant portion of Earth. With a large area of coverage, referred to as the satellite's footprint, a single transmission could reach every receiving antenna on a continent. For television broadcasts, this technique is still desirable, but it can be inefficient for telephone service or other point-to-point communications. Some satellites have used multi-beam antennas that can project a number of spot beams with small footprints (see "Spot Beams," p. 74). ACTS transmits via 51 spot beams that are more narrowly focused than those of any other satellite, allowing it to make optimum use of its allotted frequencies.

"For video coverage, large areas are absolutely ideal. HBO can hit every cable head end," says Schertler. "But if I want [point-to-point] video, like a teleconference between you and me, more data, and a lot of little calls—more faxes, say—then it's more efficient to use the spot beam."

In order to sort and route traffic, ACTS is equipped with a computer that acts as a switchboard. It directs signals to various addresses and passes them along in millisecond bursts. Several experimenters have demonstrated the versatility that can be achieved with the ACTS "hopping spot beams." In 1994 during the U.S. Army's mission in Haiti, for example, the Army Space Command set up two VSATs (Very Small Aperture Terminals, satellite dishes four feet in diameter) on the island. The VSATs sent signals to ACTS, which, through spot beams, connected Haiti with Fort Drum in New York, Fort Bragg in North Carolina, and the space command in Colorado for command briefing video conferences. In addition, the troops stationed in Haiti used the terminals for video conferences with their families back home.

ACTS' designers were guided by the knowledge that orbital space and the radio spectrum are both finite resources. Says NASA's Ronald Schertler, "It was clear we were going to run out of room."

Besides multiple beams, another way to increase the amount of information or data a satellite can transmit is to use a higher radio frequency. The higher the frequency of a radio signal, the more information it can carry in a unit of time. In their efforts to carry more traffic, satellite builders have nudged their transmitters up the electromagnetic spectrum from the C-band of frequencies, at around 4 to 6 gigahertz, to the Ku-band, at around 11 to 14 gigahertz. (A gigahertz is a billion hertz, a unit equalling one cycle per second.) By far the riskiest—and most controversial—innovation on ACTS is its use of the Ka-band of radio frequencies, at around 20 to 30 gigahertz.

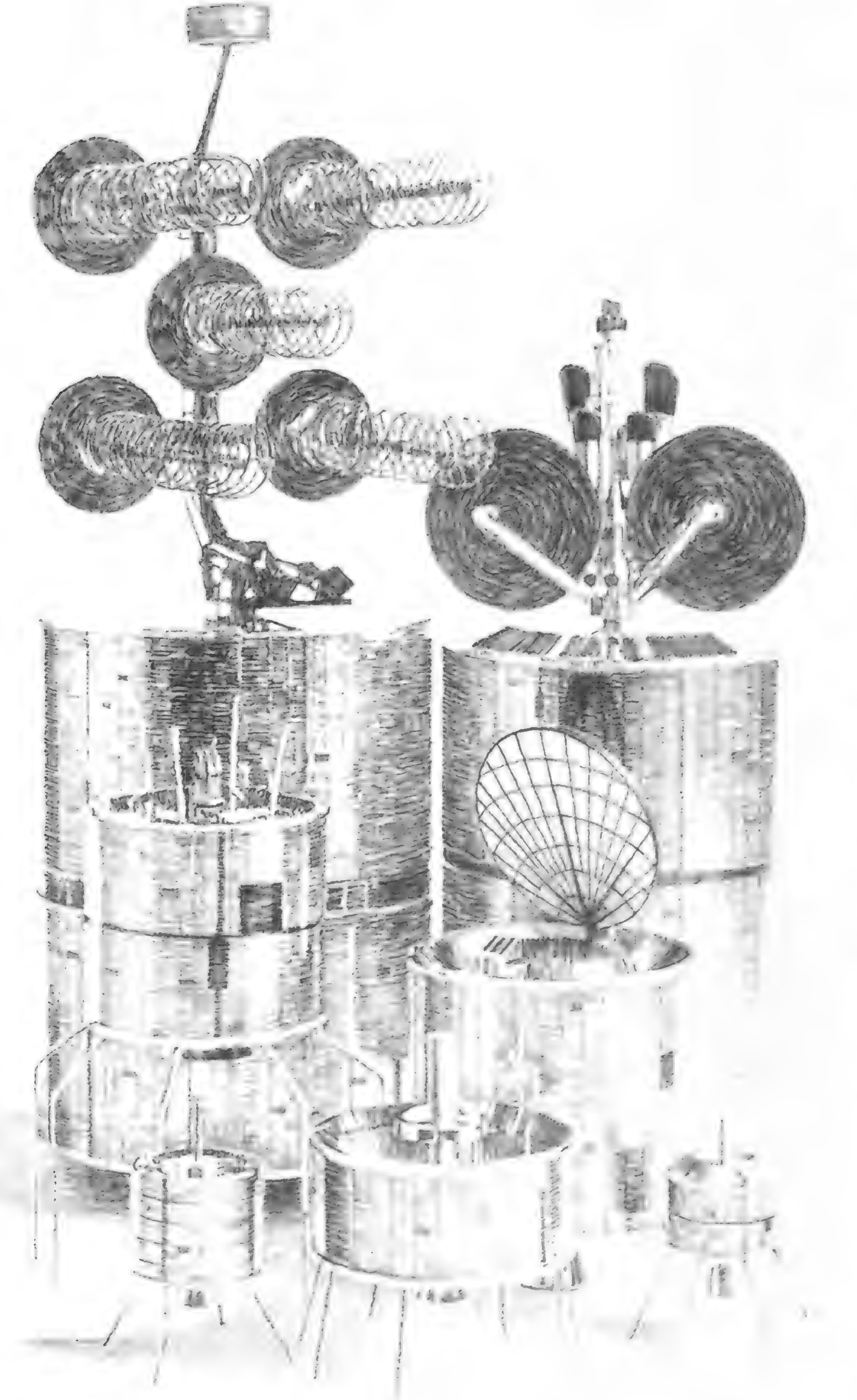
The Ka-band was attractive because a typical Ka-band satellite, using multiple transmitters, could handle several gigabits of data per second. And the region was empty. Orbital slots were filled by C- and Ku-band satellites, but Ka-band satellites would not interfere with either of these. So why weren't communications service providers moving in like hotel developers on a pristine stretch of Hawaiian beachfront?

Rain.

Signals in the Ka-band are easily broken up by buildings, trees, and, most notoriously, rain. In 1980 radio astronomer and Nobel laureate Arno Penzias told a House science committee that AT&T laboratories had decided against moving into the Ka-band. Summarizing the testimony in a 1993 *New York Times* article that pilloried ACTS, veteran space reporter William Broad wrote, "A.T.&T. dropped plans to use the Ka-band because of…the expense of developing the new technology and, most important of all, because it saw no need for new transmission bands given the increasing use of fiber-optic cables and new ways to pack more signals into existing frequencies."

So when ACTS was launched in 1993, the people at NASA who had fought for it had a lot more than its technology to prove. They believed the satellite could help invent services, and they offered it to the communications industry for research into these potential applications as well as to academic institutions for scientific research. Not surprisingly, however, NASA had trouble signing up experimenters. "We would get people interested in the program, then it would get canceled out and their confidence would erode," says Robert Bauer, an ACTS engineer who spent several years trying to sell experimental time on the satellite. "It was the old 'I'll believe it when it really flies.' "

Some of the experiments and demonstrations that ACTS did line up were in-



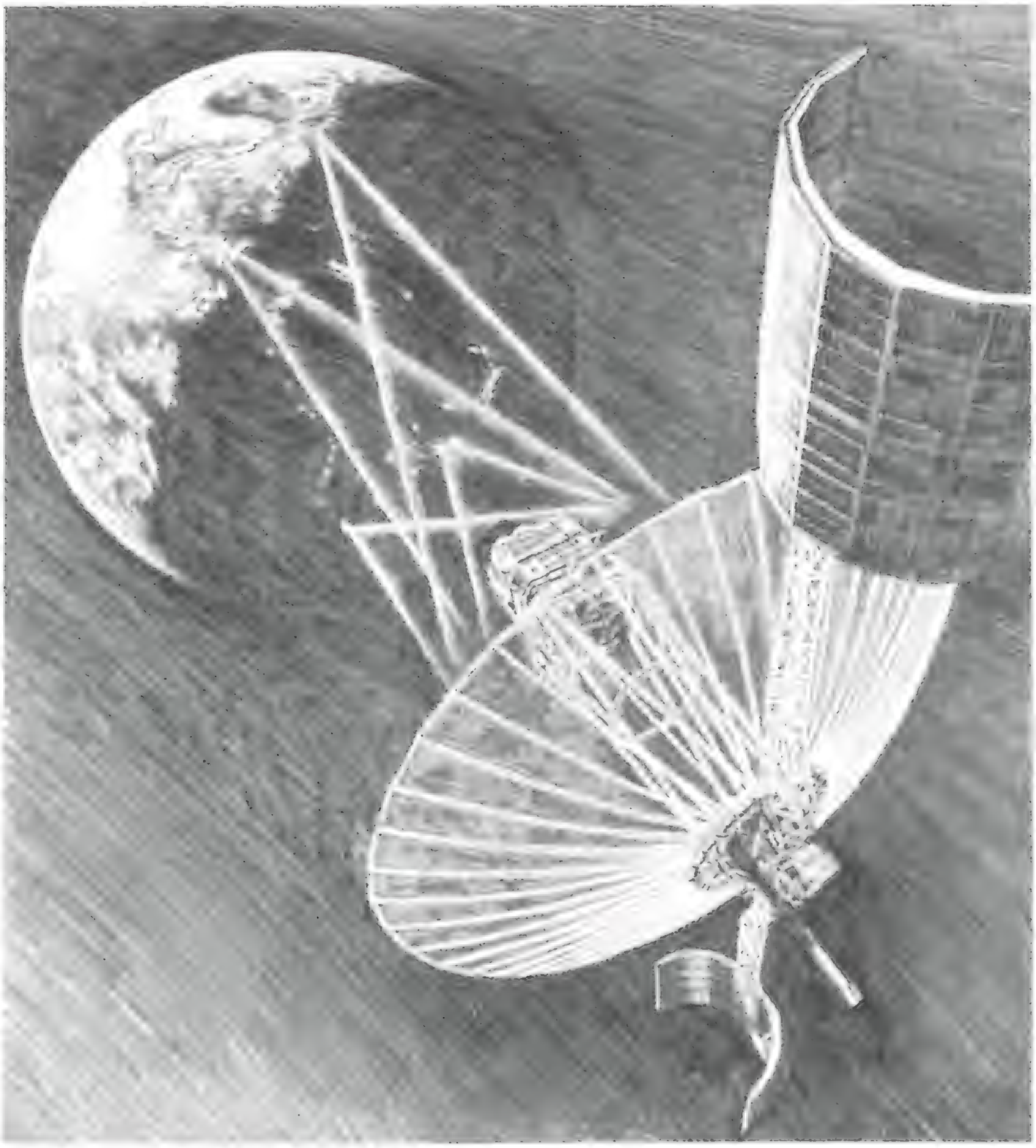
FAMILY PORTRAIT
By 1963 communications satellites had moved to geosynchronous orbit, 22,300 miles above the equator, where an object's position relative to the ground remains fixed because its period of revolution matches Earth's. The Hughes Aircraft Company built the first generation, gradually increasing their capacity and power and fitting them with ever more specialized antennas but keeping the family resemblance: a solar-cell-coated cylindrical bus.
Front row: Intelsat I or Early Bird (1965), Intelsat II (1966), Syncom (NASA,1963); Second row: ATS I (NASA Applications Technology Satellite, 1966), Anik (Canada, 1972); Back row: Tacsat (U.S. Air Force, 1969), Intelsat IV (1971).

teresting projects but not breakthroughs. A series of experiments with the Mayo Clinic, for example, demonstrated that doctors could diagnose diseases from hundreds of miles away. ACTS is not the first satellite to have made that technology available, however. Likewise, ACTS has demonstrated teleconferencing, mobile communications, and educational television targeted to remote audiences—all useful technologies but nothing out of the ordinary.

Between April and December 1995, however, ACTS did demonstrate something extraordinary. Using the satellite's broad-band capability, the Boeing Commercial Airplane Group in Seattle performed computational fluid dynamics simulations with the Cray YMP supercomputer at the NASA Lewis Research Center in Cleveland. The Boeing group transmitted data and commands, examining the characteristics of an engine inlet control system in a digital airstream and readjusting its operations in near-real time. The satellite connection to the Cray enabled the Boeing engineers to perform in hours what had taken months on their local workstations. Because of bandwidth restrictions, satellites had never before transmitted at such high data rates.

So while it is true that fiber optics systems have undercut some established satellite services, some not-so-established markets are also emerging to which ACTS and, in particular, Ka-band technology are proving very helpful. In 1987 three Motorola engineers—Barry Bertiger, Ray Leopold, and Ken Peterson—were charged with creating a new systems-level opportunity for that company. The problem Bertiger's wife had making calls from the Caribbean seemed like a promising point of departure for an organization with expertise in both mobile phones and space communications.

"We tried to come up with different ways of being able to communicate from anywhere in the world," Leopold says, "but as we went through the various options it became clear that the most reliable way to do something commercially viable was with low-flying



SPOT BEAMS

One way to increase a satellite's capacity is to equip it with directional antennas that transmit tightly focused beams. Several beams transmitted to different areas on Earth can use the same frequency band at the same time without interference. NASA's ATS-6 used this technique to pioneer direct-broadcast television in 1974. Its powerful 30-foot antenna sent educational television to small ground receivers in the Appalachian and Rocky Mountains and Alaska. ATS-6 was also the first spacecraft used for satellite-to-satellite communications.

satellites." Their model was cellular mobile phone service, which transmits through a network of fixed antennas or "cell sites." "A constellation of low-flying satellites is more akin to that than a single geosynchronous satellite sitting up somewhere," adds Leopold.

Low-Earth-orbit systems also target hand-held units. Signals from transmitters that small would be too weak to reach geosynchronous satellites but become practical when the satellite is only 420 miles high. The lower altitude also eliminates the half-second delay caused by the signal's trip from Earth to the geosynchronous satellite and back, a phenomenon familiar to anyone who has ever made a satellite call overseas.

But the architecture of a low-Earth-orbit system creates a different problem: Since a satellite at that height cannot stay in view for very long, all satellites in the constellation must be interconnected. That is, the satellite overhead at the time you make your call must be able to pass it along to the next satellite coming into view. Moreover, if the call is to someone outside your cell, it must be passed from satellite to satellite, like a complicated billiard shot, until it reaches its destination, then seamlessly maintained.

In short, the system has to operate like a giant orbiting switchboard. But this worried Leopold and his colleagues not in the least since Motorola happened to be building the switching hardware for ACTS.

"There's a big difference between ACTS and what we're doing in terms of interconnecting satellites and the volume of switching and so forth," says Leopold. "But we built the payload, so we had the expertise."

The skepticism that greeted Motorola's unveiling in June 1990 of its 77-satellite (since revised to 66) Iridium system paled next to the reaction to Calling Communications, an upstart company with plans to mount an 840-satellite system. That venture, announced in 1993, garnered little attention or respect until March 1994, when the company, renamed Teledesic, announced a partnership with two formidable backers—Craig McCaw, founder of McCaw Cellular, then the world's largest wireless-communications company, and Microsoft chairman and CEO Bill Gates, reputed to be the richest man in the United States. McCaw and Gates each put up tens of millions of dollars for 30 percent shares of the company, which must ultimately raise an estimated $9 billion to get off the ground.

"We look at ACTS as a proof of concept," says Teledesic vice president of engineering David Patterson, who started work on that system in 1990. A veteran of telephone switching research and development, Patterson was confident that a constellation of satellites could be interconnected, but he had doubts about the efficacy of Ka-band. "There was a general feeling that you couldn't use Ka-band for reliable communications because of rain attenuation and blocking by ground clutter," he says.

It's not impossible to use Ka-band in the rain; there are ways to compensate, like boosting the signal power, slowing the transmission rate, and writing code to detect and correct errors in the digital signal. What is impossible is to de-

sign a Ka-band system without knowing exactly how various degrees of "rain fade" will affect it.

"ACTS helped prove that Ka-band could be used for reliable, high-speed communications," says Patterson. "It's not just a single parameter that you're looking for. You need to know how much attenuation is associated with different levels of rain, how fast the signal changes, how it varies on both the uplink and downlink, and what power adjustments you need to make to compensate." Patterson is relying on measurements of the effects of rain on the ACTS signal to give him those answers, which he will use for his final system specifications.

Ka-band is the only frequency with enough bandwidth available for what Teledesic plans to offer—broad-band, interactive service capable of carrying everything from simple voice to high-data-rate computer and teleconferencing connections. "That broad-band consciousness came from Craig McCaw," says Edward Tuck, founder of Calling Communications. Tuck had planned a voice-only service until he held discussions with McCaw shortly after starting the company. "He said that's where the world is going—to those services you can't do with a narrow-band system. It's been a huge advantage having ACTS up there. It's brought a lot of credibility to what we're doing."

ACTS brought so much credibility to Ka-band transmission that the Federal Communications Commission received 14 applications for Ka-band frequencies at a filing deadline last October. Among the applicants: Hughes Space and Communications for its high-data-rate, 48-spot-beam, Ka-band system called Spaceway.

Victor Barajas, who is working on the Spaceway system for Hughes, used the ACTS satellite and a small terminal to demonstrate the quality of the resolution he expects his system to offer for video broadcasts and multimedia. He's planning another experiment to collect information about accessing a satellite from individual ground stations (see "The Next Generation," right).

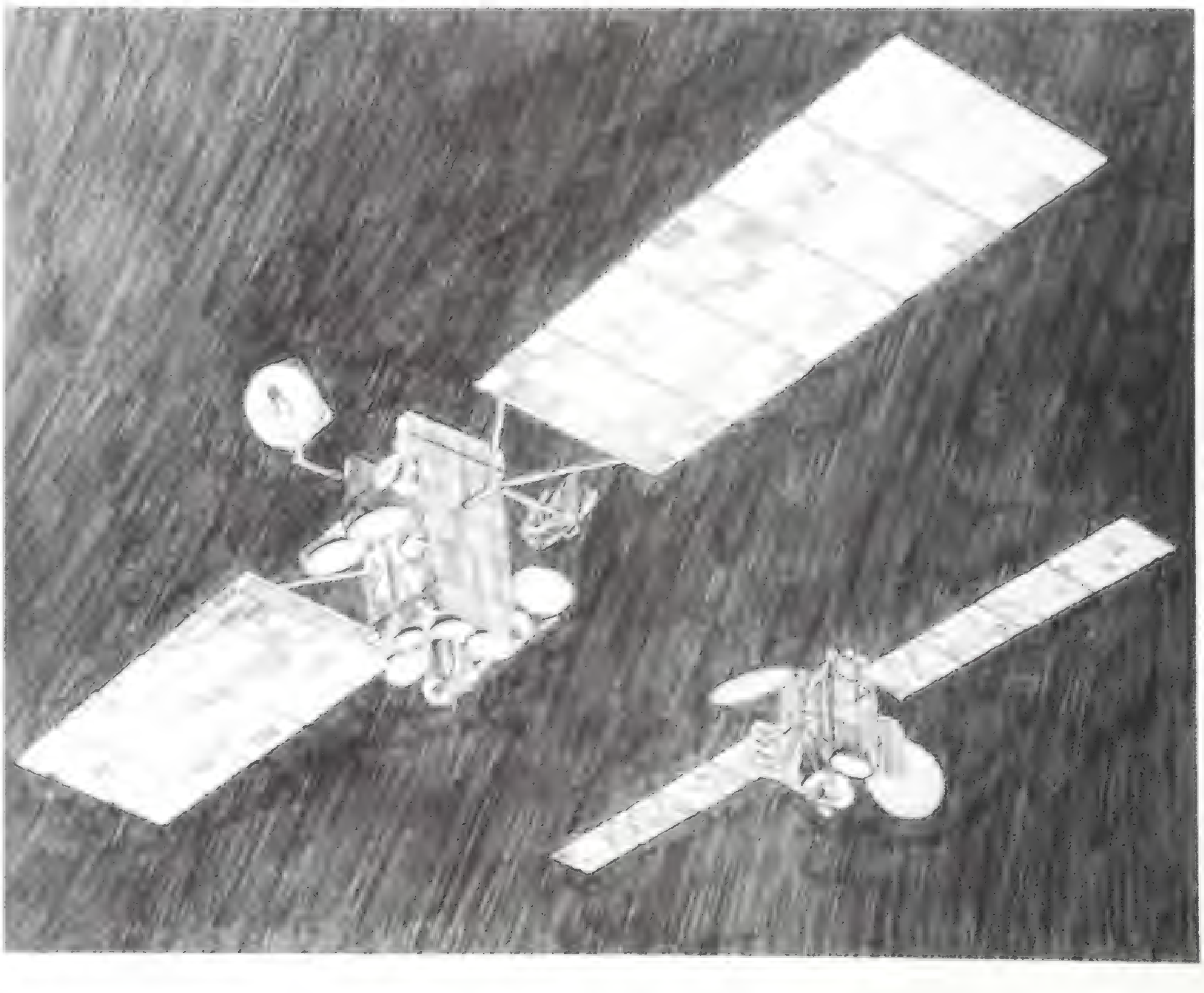
"Time heals all wounds," says consultant Walter Morgan. "It's also a good test of things—what's good, what's bad. Those 14 applications [for Ka-band frequencies]—it's basically a vindication of NASA's belief in the technology.

"Sixteen years in the consulting business and thirty-odd years in satellite communications, I've had the chance to see things come and go. Some things over the years have been hyped. But this one looks like it's going to be real. The marketing studies are there. And the whole technology of consumer electronics has changed."

ACTS is still busy nearly 24 hours a day (and will be through early 1998, when onboard fuel runs out), used by industry, academic, and military investigators. Their work has verified hopping spot beams, onboard switching and processing, and the Ka-band as the next generation of communications technology.

THE NEXT GENERATION

Telstar's ground stations were full-size buildings equipped with antennas 100 feet in diameter. To hook up to the new services, consumers can use a 25-inch dish weighing about 10 pounds. Small receiving antennas are possible because satellites like the Hughes HS-601, which broadcasts DirecTV, can transmit high-gain spot beams. For the newer services using Ka-band—Lockheed Martin's Astrolink, for example, or Hughes' Spaceway—the small dishes will send data, video, fax, and telephone signals as well as receive them.



THE MODEL MAN

Bill Topping built an empire in plastic, but he should have paid more attention to the paperwork.

Story and photographs by Chad Slattery

Lot 1823 went on the block at 4:25 p.m. The catalog showed a tiny plastic Mercury space capsule soaring over a baby-blue globe. In the photo it looked dignified. In person it looked slightly toy-like. To the hundred bidders gathered at Superior Stamp & Coin's space memorabilia auction in Beverly Hills, California, in October 1995, it looked irresistible. "It's an icon," explained auction organizer Michael Orenstein. "You can't just go out and buy a 1961 spacecraft. But you *can* get a model from that era. It's as close as an average person will get to owning a real Mercury capsule in his living room. Plus, this one's a Topping."

A Topping model, that is, and in perfect condition to boot. The Space Age baby boomers shifted anxiously in their seats as bidding opened at $200. In a heartbeat it hit $1,000 and then $2,000, and when it was over, the five ounces of plastic and metal had fetched $2,645. Fifty seconds had elapsed.

It was a record price for a mass-produced aircraft model, and that it came from Bill Topping's company surprised no one. *These are not toys*, he liked to say. *They are precision miniatures.*

In truth they were sophisticated sales aids. For the past 60 years manufacturers have promoted their aircraft, missiles, and spacecraft by selectively distributing desktop promotional models. Few of those models survive today. Those that do are avidly sought by collectors, and the most eagerly sought are those made by Topping Models.

While Bill Topping was not the first to produce miniatures for the airplane industry, he was the first to recognize that emerging postwar plastic technologies could be used to mass-produce cheap, accurate models, and he believed that he could persuade aircraft industries to use them as sales tools. "Before Bill, models were carved, one at a time, from wood," says Walt Hyatt, Topping's longtime West Coast sales representative. "It was slow and labor-intensive and so expensive that companies hoarded them. Topping sold airplane companies the idea that they should order these things by the thousands and then

Bill Topping hoped that the money he earned making precision desktop models would keep his family comfortably afloat. But his fortune, like that of the Martin SeaMaster (above), sank in a sea of troubles.

give them to anyone even remotely connected with buying their airplane. He was a master salesman."

Photos show a cheerful man of medium height and stout build, with dark wavy hair and thick-rimmed glasses setting off an open face. He was warm, quick to laugh, and radiated optimism.

He also knew his way around a factory floor. While colleagues remember Topping's gift for sales, the cornerstone of his success was a thorough knowledge of modern production engineering. He had studied mechanical engineering at Case Western Reserve University in Ohio, run a hardware factory for a few years, and then taken a job in sales at Goodyear Tire & Rubber.

Topping loved selling but hated tires; he wanted to be around airplanes. Just before the outbreak of World War II he transferred to Goodyear Aircraft to sell self-sealing fuel tanks. On a sales call at Grumman in 1942, Topping spotted a Hellcat model in a purchasing agent's office and asked to buy it for his son. Told it cost $7.50, he mused aloud that he could make a better one at half the cost with injection molding—pumping molten plastic into a steel mold (called a die), letting it cool, and then popping the model out like an ice cube from its tray. The 1,000th model would be precisely identical to the first, he told the agent. He walked out with an order for 1,500 models.

Grumman liked the result and ordered more. Buoyed by these and contracts from other Goodyear contacts, Topping quit the firm in 1943 to found Topping Models and set up shop in Akron.

Success came quickly. As the cold war heated up, companies competed fiercely for new aircraft and missile programs. Sales forces clamored for something to leave behind on a Pentagon desk. Topping's models were perfect: cheap, easy to carry, and always welcome. "He had an automatic market," says Walt Hyatt. "First place, military people would take anything for nothing. Second, they *love* models. Pentagon offices are loaded with them. Bill tapped into that."

Sales reps targeted pilots in particular. "The manufacturers gave them to all the operating groups," Hyatt says. "If you flew an F-104, you got a Topping F-104 from Lockheed. A pilot flies one, has the model at home, he's their best salesman: 'By God, that's the best airplane that ever flew!' Companies learned early that pilots grew up to be the generals who decided what to buy." (Times—and budgets—have changed. Today, a pilot who flies an F-16 a thousand hours—and knows where to write—gets a plaque from Lockheed Martin.)

As aircraft design advanced, companies insisted that models mimic sales features of the real thing. The resulting panoply of features became a trademark of Topping models. Missile trailers raised and lowered. The Vanguard rocket's nose popped off to reveal a tiny satellite. Helicopters sported panels lined with instruments. The Martin SeaMaster, a jet-powered flying boat, sliced though an ocean of clear blue plastic. Wingtip fans on vertical-takeoff-and-landing craft like the Bell Aerospace X-22 rotated through 90 degrees. The Kaman Husky's rotor blades used internal gearing to rotate in opposite directions. (Sometimes the features were too accurate: A Northrop

engineer studied the engine air intakes on Topping's Northrop N-156F approval model—the F-5 prototype—and by working backwards was able to calculate the maximum velocity at which air would enter the inlet, thus arriving at the aircraft's top speed, which was classified. Topping duly modified them.)

The dies similarly grew in complexity. From the beginning, Topping's molds were made by Ohio craftsman Joe Goldsmith. Goldsmith had learned his art through an arduous Old World-style apprenticeship, and he applied these skills to the creation of modern dies with modules that were sequentially moved, enabling complex designs to be cast with just one shot of plastic. A less imaginative toolmaker would have made the parts separately—wings, tails, engines, and so forth—and glued them together. Goldsmith, however, knew this process would demand extremely precise assembly and a highly skilled labor force. He developed ingenious molds that required workers merely to push and pull rods at various stages of the injection process.

The dies were not cheap. In June 1958, when a new Chevrolet cost $2,200, tooling for a 15-inch Lockheed JetStar came to $12,040. But they gave Topping products an unprecedented accuracy and consistency.

In the early 1950s Topping briefly branched into other industries. He created a small model of the first Youngstown Kitchens dishwasher so that salesmen could demonstrate the technology to disbelieving housewives: Hooked up to the kitchen faucet, it sprayed a stream of water through the "Jet-Tower" center column onto a rack of tiny dishes. For the Ferguson farm equipment company he produced a tractor trailing a disk harrow. Involving over 60 parts, it featured a moving gearshift and steering wheel, rolling tires, and a lever in-

According to a blurb in the Topping catalog (above), "Topping can also be used to work for you after your salesman has left. Many firms give them to customers and prospects, who display them prominently." Former Topping sales rep Walt Hyatt (left) agreed: "First place, military people would take anything for nothing. Second, they love models." Delta Airlines thanks travel agencies with a Boeing 767 in a globe (opposite, top), and the F-105 Thunderchief (opposite) scored a bull's eye with its builder, Republic.

ternally geared to raise the harrow.

Industry rewarded his innovations with nonstop orders. By today's standards, Topping's volume was enormous. In May 1957 Lockheed placed an order for 4,500 models of the F-104. Boeing ordered 3,000 707s in one week. Convair would buy over 200,000 Atlas missile variants, and North American Aviation purchased 250,000 models of its F-86 and F-100 fighters.

These large numbers easily recouped the dies' costs, and other costs were low. Goldsmith's elaborate molds—his Boeing 707 tooling had a phenomenal 39 moving parts—minimized the number of parts, reducing assembly labor. The acetate butyrate plastic that Topping used was cheap and sturdy and bonded instantly without clamps. He kept wages down by hiring hourly instead of full-time salaried labor to paint and finish models. As a result, in 1957 even a complex Martin P5M Marlin sold for under $5, and a Convair B-58 went for under $6. By 1961 Topping's sales brochure boasted that he had produced more than two million models, and he was grossing over $1 million a year. Unfortunately, he was spending even more.

Accustomed to luxury, operating in an industry afloat with defense dollars, Topping never learned to economize. He always flew first class, patronized luxury hotels, and picked up $2,000 dinner tabs after military trade shows. He owned a huge home in Akron's best neighborhood. At Christmas he gave clients $500 gifts from Abercrombie & Fitch; his wife Evelyn recalls the day he returned home and announced that

Topping's range extended beyond aircraft to include a functioning dishwasher for Youngstown Kitchens (right) and a Ferguson tractor with 60 parts. His pet project was a series of scratch-built dioramas (below) that covered the history of aviation.

Topping's empire crumbled when his 1964 World's Fair Unisphere (right) was undercut by cheap imports. Today, however, collectors have boosted the prices of Topping models sky-high. A McDonnell Mercury capsule (below) brought $2,645 last fall.

he had just bought a speedboat for a good customer at Grumman.

"Bill lived high on the hog," says Goldsmith. "He wanted to be a big shot, and he played the role. He spent more than he had coming in. But giving the gifts he gave got him nothing. He didn't need to do it; he had a great product that sold itself. It was sad."

He had always financed his business and his lifestyle by securing advances and by borrowing on purchase orders. As notes came due, Topping would simply show new purchase orders to the bank and roll the loan over. He had blue-chip clients and charm to spare; bankers viewed him as a safe bet. Then Robert S. McNamara stepped onto the field.

In 1961 Pentagon sources began warning Topping that the new secretary of defense planned to tighten controls over military spending. Topping knew that companies purchasing his models usually charged them back to the services as overhead, and he sensed that McNamara's hatchet would affect him. Looking for new markets, he approached organizers of the 1964 New York World's Fair.

The fair's focal point was a huge stylized globe dubbed the Unisphere. Topping signed an exclusive contract to produce models of it. Against Hyatt's advice, he anted up a $35,000 license fee, then borrowed $250,000 to produce 100,000 models. Full of confidence, he arrived in New York as the fair opened, stopped by a drugstore near his hotel, and saw shelves full of shiny Unispheres. Startled, he picked one up. It came from Japan.

He hadn't read the fine print. The contract gave him exclusive rights only on the fairgrounds. Other companies had secured off-site rights and then flooded the city with inexpensive knock-offs. Fairgoers bought the cheap souvenirs, not the exquisite miniatures. Topping sold just $300 worth of Unispheres.

Disaster struck again only a month later. McNamara issued a directive prohibiting military personnel from accepting any contractor gift worth over $5. Topping's cash cow dried up immediately. "The next orders we got from the companies, where they had bought 5,000 models, they bought 500," says Walt Hyatt. "Ninety percent of our business evaporated." In 1965, out his Unisphere investment and without large orders to borrow against, Topping Models collapsed into bankruptcy.

The following year Topping suffered a stroke. He retreated to his basement and for the next two decades worked on a series of 24 dioramas depicting aviation history in 1/32 scale, beginning with the Wright Flyer and ending with the ultralight Solar Challenger crossing the English Channel in 1981. His logbook records that he spent 9,436 hours fabricating the 117,000 parts. Calculating prevailing wages for a master model maker, he pegged the collection's value at $400,000, and set out to sell it.

By then, he and Evelyn had lived 20 years at a standard far below what they once enjoyed, subsisting on Social Security and her salary as a hospital receptionist. "I think Father always hoped that the dioramas would sell, that he

During the aviation industry's cold war heyday, North American Aviation ordered 250,000 models of its F-86 (right) and F-100.

would make his last statement in life, that final big sale, then be on easy street and have the money for Mother," says Topping's youngest son, John. In 1988, he crated the collection and sent it to Jack Rowe, retired manager of customer relations at Hughes Aircraft. "He was a hell of a good salesman," recalls Rowe. "But he also made everyone his friend. And it was a genuine friendship. He was just wonderful people. Now he needed help. So I volunteered to help sell them."

While Rowe was trying to sell the dioramas, a collector's market was quietly developing for Topping's promotional models. For 50 years Topping models have toppled, snapped, and been test flown by curious grandchildren into bits and pieces. Propellers break while being dusted, missiles snap off during earthquakes, and seaplanes drown in bathtubs.

Supply is diminishing just as demand is rising. A garden-variety F-104 that cost Lockheed $3 in 1957 and a collector $100 in 1992 will bring $150 today. Early Grumman jets like the Panther and Cougar in good shape average $200. The Martin P5M that sold for $5 in 1957 fetches $350—if you can get one. Walt Hyatt's observation is every collector's lament: "North American built only three X-15s. But we shipped 32,000 models of it. And just try to find one today."

Or a Convair B-58, North American XB-70, or Chance Vought XF8U-3. "I feel I'm buying a piece of aviation history," says Jonathan Rigutto, a 34-year-old nuclear medicine technologist who haunts swap meets and antique stores. "It's not just an airplane kit that you got at a store, along with three million other kids. Toppings were exclusive. And they're getting a lot harder to find.

"The Holy Grail for me would be an Avro Avrocar," says Rigutto, describing Avro Canada's 1961 saucer-shaped vertical-takeoff-and-landing craft. He bought his first model in 1990, thinking 50 would be a large collection. "But I couldn't stop there, and soon I had a hundred. Now I can't see an end in sight. There are still a lot of models out there that I want." Having now acquired some 200 models, he estimates he's spent some $20,000 on his collection.

Non-aviation Toppings are particularly rare. A New Idea Farm Equipment Manure Spreader bought by farm kids for $1 in 1952 is worth $300 today, and the Youngstown dishwasher goes for $600. But by far the greatest run-up has been in space models. The Mercury capsule auctioned for $2,645 had gone for $1,725 six months earlier, and was a relative steal in 1993 when one sold for $875. At an auction in 1994, a collector paid $1,200 for a Lunar Excursion Module that had cost Grumman $19.42 when new. Topping's seven-inch-high model of a Gemini capsule, new in the box, brought $1,100 at the same auction.

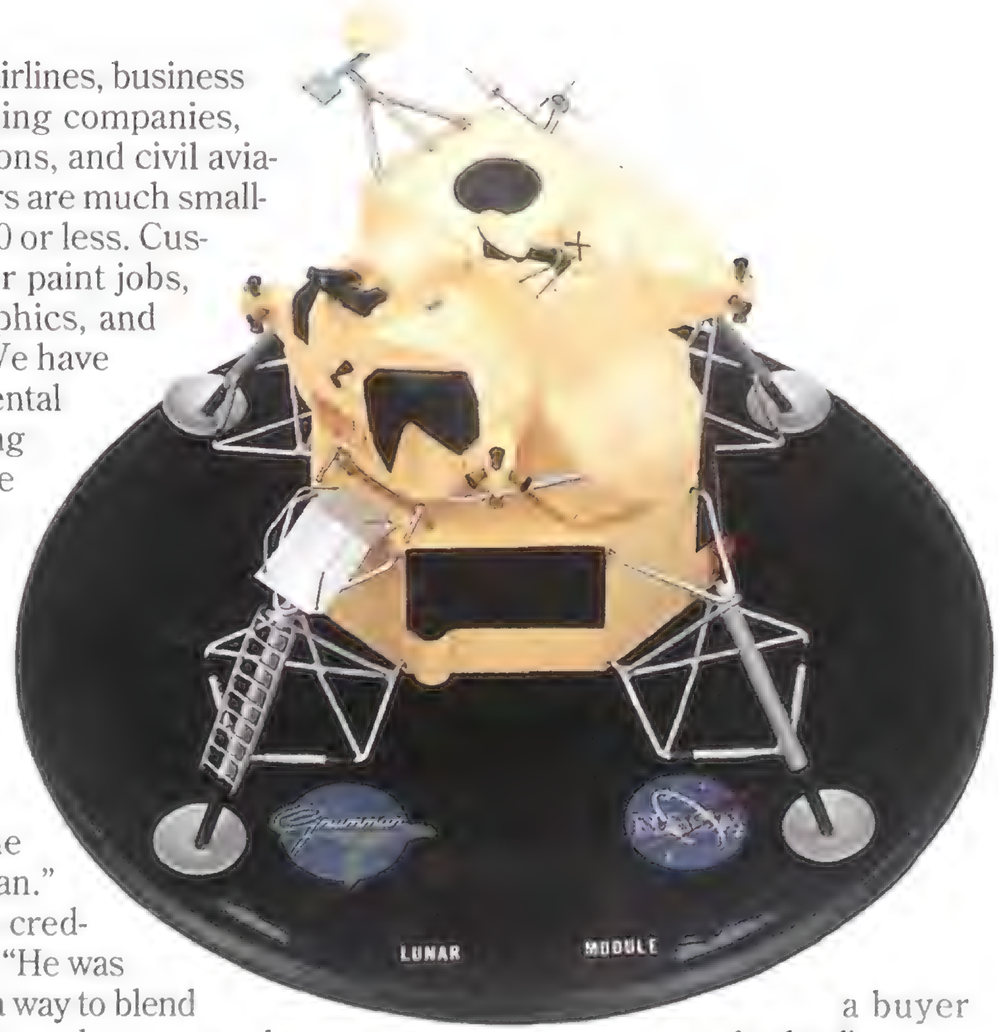
Today, like the industry they serve, model companies have downsized and consolidated. But their best customers are in the civil sector, not the military. Federal Express distributes hundreds of models to customers throughout the world. Delta Airlines thanks travel agencies and corporate travel departments with a small 767 model perched in a transparent globe. All Nippon Airways commissioned the Pacific Miniatures company to produce a model 747, intricately adorned with a schoolgirl's winning decal design, that sells in Tokyo

gift shops for $900. Western Pacific's 737, decorated with characters from "The Simpsons," is already worth triple its cost.

There is another difference that mimics the larger industry: volume. Topping regularly sold 20,000 models a month; today it takes current industry leader Pacific Miniatures six months to sell that many.

The antithesis of Topping in looks and business philosophy, Pacific Miniatures president Fred Ouweleen is having lunch in his spartan office in the Fullerton, California factory. Topping frequented four-star restaurants; Ouweleen is eating an apple from his brown-bag lunch. Between bites he compares his business with Topping's.

"His client base was 90 percent military and 10 percent civilian," says Ouweleen. "Ours is the reverse of that: We sell mostly to airlines, business jet operators, leasing companies, air freight operations, and civil aviation sectors. Orders are much smaller now, runs of 100 or less. Customers want super paint jobs, very detailed graphics, and fast turnaround. We have to meet environmental regulations Topping could never have imagined. And he focused just on the U.S.; we sell to five continents."



Ouweleen tosses the core in a wastebasket. "The best lesson Topping taught us," he says, "is to stay lean." But he is quick to credit Topping's vision: "He was the first. He found a way to blend technology and art to make great products at a low cost. Even today, when I call on my customers, I still see his models on people's desks. They're obviously cherished possessions."

Bill Topping died in a nursing home in December 1992; Walt Hyatt passed away last April. The Topping dioramas remain unsold, crated in Jack Rowe's garage. Evelyn Topping lives in a small apartment near son John, who is visiting her on a winter's day. Like his father, he is optimistic that Rowe will find a buyer for the dioramas.

If pressed, he'll bring out some old boxes, each with one or two Topping airplanes, yellowed from 30 years' storage in an attic that bakes in summer and freezes in winter. He rummages around and finds two perfectly preserved Unispheres. They are bright and still shiny, full of promise for a better world. Without a trace of irony, he explains that he has saved them for his children as a remembrance of their grandfather.

Topping's Space Age clients included North American Aviation (the Rocketdyne S3 liquid-fuel missile engine, above) and Grumman, which built the Apollo program's lunar module (top). Today Pacific Miniatures' president Fred Ouweleen (right) finds that the business has changed. "The best lesson Topping taught us is to stay lean," he says.

ROBERT LAWSON/CHECK SIX

GEORGE HALL/CHECK SIX

>SIGHTINGS<

Aerodynamicists have devised a number of ways to study airflow in the lab (see “Out of Thin Air,” p. 62), but nature sometimes obliges with a lesson in the field. Temperature, humidity, and airspeed conspire to create an evanescent portrait of airflow by causing moisture in the air to condense and stream off an aircraft in clouds, sheets, and ribbons. When captured on film, these natural visualizations of wing-body flow, high-speed flow, and vortical flow provide researchers with confirmation of wind tunnel and computer simulations—and the occasional surprise.

“With the humidity and dew point right,” says photographer George Hall, “pilots can make these nice big doughnuts if they fly at Mach .98.” Hall caught the F-14 at right at an airshow at Point Mugu, California, while Robert Lawson photographed the Tomcat above making a high-speed pass alongside an aircraft carrier.

And Lo! An Angel Appeared

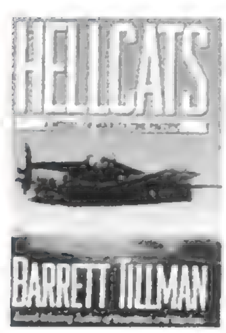
MCDONNELL DOUGLAS

Blue Angels—50 Years of Precision Flight *by Nicholas A. Veronico and Marga R. Fritze. Motorbooks International (1-800-826-6600), 1996. 128 pp., color and b&w photos. $24.90 (incl. shipping).*

Like a handbook for the U.S. Navy's Flight Demonstration Squadron, *Blue Angels* includes pretty much all you need to know: the team's history, a roster of airplanes along with their good and bad points, training regimes, mishaps, and crashes. Tales of trial and error are scattered throughout: parachuting a dummy pilot full of sand and sawdust out of an SNJ painted to resemble a Mitsubishi Zero in 1946, tying three F9F Panthers together with rope for takeoff and participation in diamond formation maneuvers in 1949, and the inadvertent demonstration of the McDonnell F-4J Phantom's transonic capability in 1969 in British Columbia. The big fighter's sonic boom knocked out all the windows for eight city blocks; the next day, the windows, now boarded up, sported signs reading "Yankee Go Home."

There are some real gems for trivia fans—the origin of terms, for example. The team name was plucked out of a listing for a nightclub in the "Goings On About Town" section of the *New Yorker* in 1946. The name of a diamond formation maneuver was also borrowed from pop culture: "There was a commercial for Nestle's chocolate on TV at that time," says former team leader Ken Wallace, "and a dog in the commercial was named Farvel. On the spur of the moment I decided to call the maneuver the Farvel. No better reason than that."

—Patricia Trenner wonders where the U.S. Air Force Thunderbirds came up with the term "whifferdill" for one of their maneuvers.



Hellcats: A Novel of War in the Pacific *by Barrett Tillman. Brassey's, 1996. 338 pp., $24.95 (hardcover).*

Over the years my reading addiction has changed from novels to history, but I couldn't let this one go by. Barrett Tillman writes well-regarded reference books, including an operational history of the Grumman F6F Hellcat. Who wouldn't want to meet the powerful Hellcat as the hero of a novel?

Within 20 pages, however, it was Tillman's anti-hero who engaged my sympathy. Hiroyoshi Sakaida is as sympathetic a character as any I've encountered recently, and I say that without shying away from some of the brutality of the Japanese style of warfare

in World War II. Shot down over Truk Atoll along with some U.S. Navy pilots, he briefly hopes he can meet the Americans. "No, it would never be permitted," he tells himself. "Besides, the poor fellows already were undergoing interrogation, then they would surely be killed. It was procedure—everybody knew that." (His name, by the way, is probably a wink to aviation writer Henry Sakaida, who helped Tillman with Japanese sources.)

Following the convention of such yarns, the author cuts back and forth between the opposing pilots: early combat, retraining, groping toward their inevitable meeting over the Pacific. Compared to Sakaida, the Americans are so darned nice that they might have stepped out of a 1940s comic strip or radio serial. Hellcat pilots may smoke and drink, but they never cuss, and sex is only a rumor. No matter. Petty Officer Sakaida carries the story from Truk to the Homeland to the escort of a suicide squadron commanded by Lieutenant Kono, another memorable character, who lives only to avenge his injuries by "body-crashing" (the literal translation of *jibbaku*, the final suicide dive of a kamikaze pilot and a term Tillman uses throughout) a U.S. aircraft carrier.

And both sides fly and fight like demons in some of the finest combat sequences I've ever read, whether as fiction or as history.

—Daniel Ford wrote about the Brewster F2A Buffalo in the June/July 1996 issue.

SR-71 Revealed: The Inside Story *by Richard H. Graham, Colonel, USAF (ret.). Motorbooks International (1-800-826-6600), 1996 . 220 pp., b&w photos, $19.95 (paperback).*

Rich Graham, a former SR-71 pilot and squadron and wing commander, has given us the ultimate insider's book. From his pilot's-seat successes to his demoralizing defeat in the Pentagon, where he fought officials up to and including the Air Force chief of staff in an attempt to save the SR-71 program, Graham shares his passion, joy, and outrage. Although it happened long after Graham had already retired from the Air Force, it seems a fitting postscript to this book that last year Congress authorized bringing three mothballed SR-71s out of

Briefly Noted

REFERENCE

Brassey's World Aircraft & Systems Directory, *chief editor Michael Taylor. Brassey's, 1996. 672 pp., b&w photos, drawings, charts, tables, $99.95 (hardcover).* A rival to *Jane's All the World's Aircraft* at a fraction of the price, this compendium presents its taxonomy by aircraft type and mission, with nation of origin as a sub-category. It covers a lot of ground by abridging the information for each individual aircraft.

A PAIR OF BOEING BOOKS

Flying High: The Story of Boeing and the Growth of the Jetliner Industry *by Eugene Rodgers. Atlantic Monthly Press, 1996. 512 pages, $25 (hardcover).* The history of the company as told in its files and documents, from the author's perspective as a business-school professor. **Contrails: A Boeing Salesman Reminisces** *by Eugene E. Bauer. TABA Publishing (360-825-9709), 1996. 326 pp., $12.95 (paperback).* A fascinating account of how the world's leading airliner store sold its goods in South America by a man who served as head peddler.

COMPUTER COMPANION

Cross Country: 30 VFR Flights for Microsoft® Flight Simulator® 5.1 *by Alfred Poor, Desktop Wings (800-848-6198), 1996. 255 pp., b&w photos, charts, and software (situation files on floppy diskette), $24.90 including P&H (paperback).* For those who prefer to have their flight plans done for them, this package provides detailed instructions for trips on the world's most popular flight simulator.

DINOSAUR DEBUNKING

The Great Dinosaur Extinction Controversy *by Charles Officer and Jake Page. Addison-Wesley, 1996. 224 pp., $25 (hardcover).* The impact theory is as dead as…well, the dinosaurs, say a biologist and a leading science writer.

FOR MODELERS

20th Fighter Group *by Ron MacKay,* **F6F Hellcat** *by Bert Kinzey,* **Walk Around P-51D** *by Larry Davis. Squadron/Signal Publications, 1996. At hobby shops.* All the detailed close-up photographs hardcore modelers crave.

retirement and refurbishing them.

Often using the words of his fellow pilots and reconnaissance systems officers, he has captured the unexcelled teamwork of this smallest fraternity of flight—those who flew operational missions in the Blackbird. Both the airplane and the crews that flew it were called Habus (pronounced hah-*boos*), because Okinawans thought the sleek, secret, Mach-3.35 strategic reconnaissance aircraft based in their country resembled a local snake. As Graham makes clear in some of his most interesting and disturbing passages, senior Air Force officers often treated the SR-71 program as if it were a snake. And he names names.

Forty-seven pages of "Technical Features" may put some readers off, but if so, they'll miss the intensity of trying to find a tanker in the middle of the night over the Pacific Ocean in zero visibility at several hundred miles an hour. Or the elaborate, if goofy, pranks these warriors without weapons used to spring on each other.

In a society in which television has trained us to expect information to be packaged as entertainment, Graham's book is not likely to find a broad audience. But it is noteworthy for its richness of detail and authenticity, and for the larger goal the author has accomplished. As one who was there, he has captured a piece of aviation history that was out on the edge of technology, space, and the cold war.

—Bob McCafferty is a former TV newsman who covered the SR-71 after serving six years in the Strategic Air Command.

The Simple Science of Flight: From Insects to Jumbo Jets *by Hank Tennekes. MIT Press, 1996. 152 pp., b&w illustrations, $28.00 (hardcover).*

We've come a long way in our understanding of birds and flight since the mid-19th century, when, breaking with contemporary wisdom, Britain's Duke of Argyll realized that winged creatures flew without the aid of hot air; why else would they drop out of the sky when he blasted them with his shotgun? Tennekes' slim new book comes as a pleasure for those who realize there's valuable information to be gained about mechanical flight from birds.

But now it's confession time. Sure, I made it all the way to page 24 of Stephen Hawking's notoriously dense *A Brief History of Time* before suffocating in a black hole of scientific ignorance. In *Simple Science* I got only to page 3 and the sentence "According to a version of Newton's Second Law of Motion that is explained in detail in Chapter 4, the force generated by the airflow around the wings is proportional to d times dV" when that choking sensation started to overcome me. But I persevered. First I stalled by peeking at all the lovely drawings of birds, bugs, and Boeings (though mostly birds), then I went back through and studied some of the more interesting tables (mainly one that compares everything that flies, from the fruit fly to the 747), before collecting my courage and diving back in at page 3.

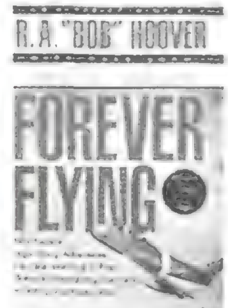
I eventually found *Simple Science* much more cogent and engaging than other aerodynamics texts I've forced myself through, most notably Theodore von Karman's respected 1954 tome, *Aerodynamics*. "The quickest way to get used to new concepts is to play with them," writes Tennekes, and so he jam-packs his text with junk food for the aeronautical mind. He proves, for example, that a loaded car is more efficient than a train, and that an airplane

is the most efficient mode of transportation of all—up to supersonic speeds, that is. And he shows why it took so long for human-powered flight to develop: A bird can generate 100 watts of power per kilogram of muscle mass, while a human can generate only 10 watts.

While this book is not for everyone, clever people might find enough learning within its pages to begin designing their own flying machine. Others might enjoy having bird flight explained from an engineering perspective. The rest, like me, will get lost in formulas early, but still enjoy the pictures.

—Phil Scott once started building a wood-and-fabric airplane, but found he preferred watching The New Yankee Workshop.

Forever Flying *by R.A. "Bob" Hoover with Mark Shaw. Pocket Books, 1996. 291 pp., b&w photos, $24 (hardcover).*



Test and airshow pilot Bob Hoover grew up in a time when men were men and cigars were more than a good smoke, so if you're offended by references to flatulence, exposed genitalia, and shopworn sexist jokes, don't read his autobiography. However, if you can bear in mind that cultural values were different fifty years ago, you'll enjoy this lively story, a test pilot's saga of jumping in and out of airplanes that were screwing up, going down, catching fire, losing power, collapsing landing gear, sliding on bellies, and generally trying to kill him day in and day out.

Life was not all aerial adventures. Along with the broken bones, fractures, and other assaults that test flying entailed, Hoover survived a terrifying wartime spell in a German prison camp, where his captors once stood him in front of a firing line and progressed through "Ready…Aim…" and the cocking of rifles before returning him to his cell. Later, in talking about his combat flying in Korea, he displays the unquestioning devotion to duty prevalent in that era: "Since I would be flying combat, my fellow pilots were briefed to shoot me if for any reason I had to go down over enemy territory. My knowledge of the new supersonic F-100, which I would soon be testing, made me a potential liability if I fell into the hands of the enemy. I understood and accepted the order."

Life was indeed different then. Happily, Hoover won all his battles with airplanes,

the Germans, and the Federal Aviation Administration, which in 1994 revoked his medical certificate for highly questionable reasons and sheepishly returned it 18 months later. Today, still flying airshows and revered by fellow pilots, Hoover is a legend in his own time. With the exception of some sloppy misspelling of aircraft names—"Newport," "Air Cobra," "Henkel"—his autobiography is a well-told tale of a charmed life.

—Patricia Trenner had the good fortune to fly with Hoover in his twin-engine Shrike Commander at the 1979 Reading Airshow.

Preview

NOVA: Top Gun Over Moscow, *scheduled broadcast date Tuesday, November 12, 1996, 8 pm. PBS (60 minutes).*

Mark your calendar. This history in contrasts between the Soviet and U.S. air forces is one of NOVA's best efforts ever in the aviation field and will represent a "must see" for all military aviation enthusiasts. There are some familiar faces, too: writer Jeff Ethell (whose thumbnail pilot reports are featured on the *Air & Space/Smithsonian* Web site) and Von Hardesty, a curator at NASM's Department of Aeronautics and a specialist in Russian aviation history. Both contribute extensively on camera.

Some conventional wisdom concerning the Soviet (and current Russian) air force gets debunked in the course of the narrative, and some of the differences between its tactics and those of the west are examined all the way back to their historic roots. Anyone wondering how a battle between these two mighty forces might have turned out may not find a direct answer here, but you'll arrive at the end of this solid hour of television with enough knowledge to reach your own conclusion.

—George Larson

Martin Aircraft 1909–1960 *by John R. Breihan, Stan Piet, and Roger S. Mason. Narkiewicz/Thompson, 1995. 208 pp., photos and drawings, $29.95 (paperback).*

Glenn Luther Martin built his first aircraft, a biplane, in California and flew it a distance of 100 feet at an altitude of two feet in 1909—the same year Louis Blériot flew across the English Channel.

It's Martin, though, who's more of a hero in Maryland. His aircraft

manufacturing company moved from Cleveland to Middle River, Baltimore County, in 1929 and from then until 1960 employed thousands to design and build more than 60 types of airplanes. The company still builds jet engine thrust reversers, missile launching systems, tail cones, and nose caps at the site. This new book, probably the most complete catalog of Martin aircraft available, provides photos, mechanical drawings, and specifications (engines, dimensions, weights, performance) for all Martin models and makes an excellent addition to any library.

The most famous Martin airplanes are the Clippers—pioneer transoceanic passenger seaplanes built in the 1930s. Martin sold three to Pan American Airways, losing money on the deal, and all of them eventually crashed. A later model went to the Soviet Union, this time at a profit, and it flew until it was retired for lack of spare parts.

Glenn Martin was one of the first to envision aircraft as weapons and made much of his fortune selling them as such. In the early 1920s, General William (Billy) Mitchell flew a modified Martin bomber to demonstrate its use against battleships. Both the British and the French bought Martin A-30 bombers at the beginning of World War II—and used them against each other when the Vichy French tried to defend North Africa. Early versions of the Martin B-26 Marauder with short wings crashed a lot, but improved versions were effective against German forces in Europe.

By noting that his first airplane "was a near-copy of [rival pioneer] Glenn Curtiss's biplane," the book hints at the condescension that Martin—a car dealer and seat-of-the-pants aviator—inspired in some of the engineers he hired in later years.

The photos of aircraft will thrill readers more than anything else in the book, but the best of the lot is captioned: "Glenn Martin, pilot and hero, strokes Mary Pickford's hair in 1915 movie [*The Girl of Yesterday*]." Pickford ("America's sweetheart") is seated in the front cockpit of an airplane. Martin is in the rear cockpit holding one of her braids and wearing an expression that says, "My mother doesn't approve of actresses."

—John Goodspeed is a columnist and critic for various Baltimore publications.

CREDITS

Redemption. In addition to serving as NASA's chief scientist for the Hubble Space Telescope program, Edward J. Weiler is director of NASA's recently created Origins program, a 25-year project to develop spacecraft and telescopes that will seek out the origins of galaxies, stars, and planets. Karen Jensen is an associate editor at *Air & Space/Smithsonian*.

Second-Hand Smoke. Having spent nearly 50 years as a product support representative in the aviation industry, O.H. Billmann is now a frequent contributor to Flights & Fancy.

Search and Destroy: The War on Counterfeit Parts. In reporting this story, contributing editor William Triplett followed the debate over bogus parts for more than a year. His last feature, "The French Succession," appeared in the Apr./May 1996 issue.

NASA's X-33. Based in Alexandria, Virginia, Bruce D. Berkowitz often writes about space issues and the launch vehicle industry.

Bless Our Happy Missile Silo. Freelance writer Nate Ferguson is an airplane and glider pilot who lives in Utah.

Jay Koelzer, a freelance photographer living in Boulder, Colorado, recently finished up a 12-year stint as a staff photographer at the *Rocky Mountain News* in Denver.

Going Vertical. Contributing editor Stephan Wilkinson's last story was "Forty Years of Falcos" (Aug./Sept. 1996), another chapter in his ongoing saga of building and maintaining his own airplane.

Out of Thin Air. A writer in Alexandria, Virginia, Carl Posey wrote "In the Grip of the Whirlwind" (June/July 1996).

Opening ACTS. Frank Kuznik is a frequent contributor to *Air & Space*.

The Model Man. Chad Slattery has contributed photography to *Air & Space* since its inception; this is the first feature he has also written.

Slattery has collected promotional models for the last five years and is preparing a book on them. He welcomes e-mail queries from other collectors at 102657.1225@compuserve.com.

A Birdwatcher's Paradise. Gord Struthers is city editor at the Saskatoon *Star Phoenix*.

CALENDAR

October 1
"Wendell F. Moore and His Dream Machines." This new exhibit, which features the Bell Rocket Belt and a zero-gravity maneuvering unit, goes on display. Buffalo Museum of Science, Buffalo, NY, (716) 896-5200.

October 1–6
8th Air Force Historical Society Reunion. Orlando, FL, (800) 833-1942.

October 4 & 5
Northwest Arkansas World War II Museum Association Fall Fly-In. Smith Field, Siloam Springs, AR, (501) 524-4103.

October 5
Auburn Air Fair. Auburn Municipal Airport, CA, (916) 637-5107.

Chick 'n Hawk Cross-Country Air Race. Bowman Field, Louisville, KY, (502) 241-9173.

Salute to Naval and Marine Corps Aviation. Planes of Fame Air Museum, Eden Prairie, MN, (612) 941-2633.

October 5 & 6
Daytona Skyfest. Daytona Beach International Airport, FL, (800) 854-1234.

October 6
Open Cockpit Sunday. New England Air Museum, Bradley International Airport, Windsor Locks, CT, (860) 623-3305.

October 9–13
Silver Wings Fraternity National Convention and Fly-In. San Diego, CA, (800) 554-1437.

October 11–13
Wilmington College Aviation Career Seminar. New Castle County Airport, DE, (302) 328-9401.

October 12 & 13
Alabama Air Fair. Huntsville International Airport, AL, (205) 309-0020.

October 13
Air- and Spacecraft Model Contest and Swap Meet. Harborcreek, PA, (814) 864-3756.

October 13–17
Air Traffic Control Association Annual Meeting. Opryland Hotel, Nashville, TN, (703) 522-5717.

October 19
Back to Basics Air Race. Santa Monica Airport, CA, (310) 450-2788.

October 24–27
459th Bombardment Group (15th Air Force) Reunion. Hilton Hotel, Cocoa Beach, FL, (407) 799-0003.

November 2 & 3
Wings 'n Things Fly-In. Lakeland Linder Regional Airport, Lakeland, FL, (813) 251-1820.

November 5–10
Airshow China '96. Zhuhai Airport, Guangdong, People's Republic of China, (201) 652-7070.

November 19–21
National Business Aircraft Association Annual Meeting and Convention. Orlando, FL, (202) 783-9362.

“The Satellite Sky” Final Update

This will be the final “Satellite Sky” update to appear in this space. For future updates, visit the magazine’s Web site at www.airspacemag.com.

New launches

90 to 300 MILES

Progress M-31
5-5-96 TT

Progress M-32
8-1-96 TT

300 to 630 MILES

TOMS-EP
7-2-96 L-1011

6,200 to 13,700 MILES

GPS-26
7-16-96 CAC

21,750 to 22,370 MILES

Intelsat 709
6-15-96 KOU

Arabsat 2A
7-9-96 KSC

Turksat 1C
7-9-96 KOU

Apstar 1A
7-3-96 XI

Inoperative but still in orbit

300 to 630 MILES

Cosmos 2310

6,200 to 13,700 MILES

GPS-9

21,750 to 22,370 MILES

Cosmos 2282
Palapa B-1

Deletions

90 to 300 MILES

Cosmos 2293
down 5-13-96

Cosmos 2331
down 6-11-96

Launched but not in orbit

90 to 300 MILES

STS-78 U.S. research	6-20-96	down 7-7-96

DATA: SAUNDERS KRAMER

FORECAST

In the Wings...

American Renaissance. The Saturn V rocket is the most revered symbol of American engineering that ever left a launch pad. When the National Air and Space Museum restored one of the giant launchers that had been left to the elements in Florida, the project became a patriotic duty.

PLUS—Unique Poster: The Saturn V. A five-foot-long replica of the Wernher Von Braun team’s engineering drawing shows the world’s biggest rocket in exquisite detail.

Burial at Sea. After the U.S. Navy canceled the A-6 Intruder program, manufacturer Northrop Grumman found itself with 100 airplanes to dispose of. After the air museums had their pick, a group of Florida fishermen knew just what to do with the leftovers.

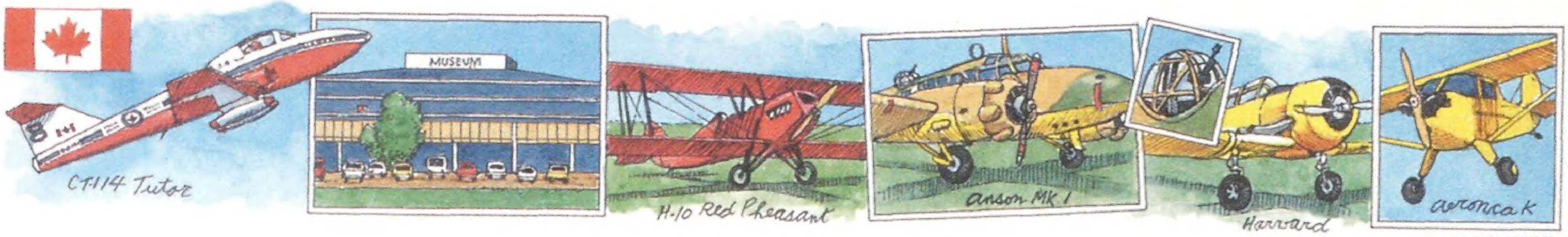
They’re Number One. The best helicopter pilots in the world are Russian. At least they were this summer at an international competition in Oregon.

Escape to Thailand. In the chaos that marked the end of the Vietnam war, 933 U.S.-supplied aircraft fell into the hands of the North Vietnamese. Another 166 would have followed, had it not been for some quick thinking and courageous flying.

The Missile Flap. Before the intercontinental ballistic missile became a fact of life, the U.S. Air Force faced the problem of how to make a nuclear strike against the Soviet Union fast, accurate, and survivable. Which would be a safer bet: a winged cruise missile or the still-futuristic ICBM?

Blimp Base. Since the Tillamook Naval Air Station Museum in Oregon once housed U.S. Navy airships, it now has plenty of space to display 25 historic—and airworthy—aircraft.

The Grumman on the Moore Farm. For an impressionable boy in rural New York, a Navy fighter, a gallant young pilot, and a bright June day formed a lasting memory of the summer of 1940.



JOHN HEINLY

A Birdwatcher's Paradise

Travelers approaching the city of Moose Jaw on the TransCanada Highway have been startled by a dramatic sight: Above the wheat fields stretching to the horizon in all directions, nine bright red, blue, and white CT-114 Tutor jets roll through aerobatic maneuvers in alarmingly tight formation.

Four years ago, the staff at the Western Development Museum's Moose Jaw branch decided to take advantage of the drama of that local spectacle. The museum developed a series of exhibits centered on the Snowbirds, the Canadian military's air demonstration team, which is based on the southern outskirts of the city.

Though the museum covers the history of all forms of transportation ever used in Saskatchewan—everything from birchbark canoes to the first Ford automobiles to sounding rockets—nearly half of its floor space is now devoted to aviation and the Snowbirds. A visitor enters the Snowbird galleries through a corridor with dozens of photographs and prints showing the Canadian military's tradition of aerobatic flying. Back in 1929, Canada's first team, the three-man Siskins, dazzled crowds in Armstrong Whitworth Siskin IIIA biplanes; in the early 1960s, the Golden Hawks entertained audiences in Canadair-built F-86 Sabres. To help celebrate the nation's 1967 centennial, the military formed the Royal Canadian Air Force Golden Centennaires. Instead of following the demonstration-team tradition of showing off the latest in their nations' fighter technology, the Centennaires opted to fly the Canadair Tutor, a 1960s-vintage two-seat, single-engine turbojet trainer. The Tutors were cheaper to operate than frontline fighters, and their agility enabled the team to perform in larger, tighter formations.

After completing 100 centennial-year performances, the Centennaires were disbanded. Their specially fitted Tutors were stripped of their gold, blue, and red paint and shipped to Moose Jaw to serve as trainers at the air force base there. By coincidence, the Centennaires' former commander, Colonel O.B. Philp, was appointed commander of the base in 1969, and on his first inspection tour he came across five of the former Golden Centennaire Tutors. Philp set about reviving an air demonstration team, and two years later the Snowbirds put on their first official performance.

The museum includes a replica of the lounge where the Snowbird pilots relax after training flights at their base. The lounge opens onto re-creations of the Snowbirds' briefing room and tarmac. A T-133, the training version of the Lockheed P-80 Shooting Star, hangs from the ceiling; built by Canadair in the 1950s, this aircraft model was at one time used by the Snowbirds' coordinator/narrator. Beneath the T-133 stands a Tutor in the livery familiar to airshow fans across North America.

Western Development Museum, Box 185, 50 Diefenbaker Drive, Moose Jaw, Saskatchewan, Canada S6H 4N8. Phone (306) 693-5989. Hours subject to change; call before visiting. Adults $4.50, seniors and students $3.50, kids $1.50, pre-schoolers free; for admission-film combination, add $1.50.

Other Snowbirds exhibits give visitors a taste of the challenges aerobatic pilots face. You can strap yourself into a Tutor's seat and check out the aircraft's instruments. Or you can enter a mockup of the tower at the team's base and follow an audio-visual presentation on controlling air traffic at a busy flight training center. The tower also offers a chance to fly a Tutor simulator.

Those with strong stomachs can fly with the Snowbirds at the museum's Cinema 180, where a 70mm film is projected on a 19- by 45-foot curved screen. A sign on the door warns away people with vertigo or a tendency to get motion sickness. The short film features the Snowbirds' maneuvers up close and loud, complete with roaring engines and crackling radio traffic.

Other aviation artifacts at the museum include a curious Canadian-made recreational vehicle called the Chinook, an 11-foot plastic platform with a "lift fan" that produced a thin cushion of air beneath the craft, enabling it to hover less than a foot above land or water. The museum also has what is believed to be the oldest aircraft in the province: a hulking 1927 Red Pheasant, originally bought by Saskatchewan's Cherry Airways and later used as a barnstormer. Flanking the Pheasant are a 1937 Aeronca and a DH 60 Gipsy Moth biplane that was once used to ferry supplies to surveyors and trappers working in the Northwest Territories.

The museum has a large gallery devoted to Saskatchewan's role in the British Commonwealth Air Training Plan, which prepared thousands of air crewmen for combat during the second world war. Trainers on display include a DH 82 Tiger Moth, a Harvard Mark IV, a Cessna Crane, and an Avro Anson Mk 1.

The Mk 1 is the only completely restored example in North America. The restoration took 23,000 hours of labor, donated by the Vintage Aircraft Restorers, a team of 18 retirees. The leader, 80-year-old Don O'Hearne, served as an aircraft mechanic under the air training plan. The Anson is the third project he and his volunteers have completed. They are now working on a Fairchild Cornell for the air training plan gallery and a fiberglass mockup of a Tutor's forward section that will give children a chance to imagine themselves at the controls with the Snowbirds.

O'Hearne says kids today just don't seem impressed by the long hours and volumes of knowledge that went into restoring the trainers. "They always ask us: 'Where's the fighters?' " he says. "They want to see Spitfires and Hurricanes. They don't realize that no one flew a Spitfire that wasn't in one of these airplanes first."

—Gord Struthers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